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U.S. DEPARTMENT OF COMMERCE
Environmental Science Services Administration

HURRICANE CAMILLE

A Report to the Administrator

September 1969

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FOREWORD

On August 22, 1969, I requested Donald C. House, Chief, Atmospheric Science Services Division, Office of Plans and Programs, to undertake, immediately, an extensive review of the effectiveness of the natural hazards warning system during the period of hurricane CAMILLE. He was directed to review the performance of all elements of ESSA as well as those elements of the Department of Defense that participated in providing data for the warning service. The purpose of this survey was to establish where the warning system performed effectively and where deficiencies existed that required remedy.

The enclosed report by Mr. House and his group represents their findings on the warning service, its present capabilities, and its limitations. This report reveals clearly how effective community preparedness action strongly identified with and geared to the meteorological warning system can make possible significant savings in lives and greatly reduce the human suffering that follows disasters of this nature. I am impressed by the tremendous cooperation among Federal, State, and local authorities, the news media, and the public when the possibilities of disaster were identified and time was still available to do something about it. The success of those actions is a tribute to the diligence and dedication of personnel involved.

Robert M. White

Robert M. White
Administrator
Environmental Science Services Administration

PREFACE

The Survey Team included Dr. Harry P. Foltz, Chief, Public Weather and Warning Branch of the ESSA Weather Bureau's Office of Meteorological Operations; Professor Frederick Sanders*, Department of Meteorology, Massachusetts Institute of Technology; Mr. G. A. Baker, ESSA Office of Public Information; Mr. Charles Carpenter, Regional Emergency Warning Meteorologist, ESSA Weather Bureau Southern Region; Mr. Robert Beck, Deputy Chief, Telecommunications and Space Services Division, ESSA Office of Plans and Programs; Mr. Robert E. Hairston, Chief, Aerial Reconnaissance Coordination, Atlantic Hurricanes, National Hurricane Center, Miami, Florida; and Commander L. J. Underwood, U.S. Navy, Commanding Officer, Fleet Weather Facility, Jacksonville, Florida. The team was divided into two working groups. One team, consisting of Dr. Foltz, Mr. Baker, and Mr. Carpenter, proceeded on August 26, 1969 to the hurricane-stricken coastal area. The other group, consisting of Professor Sanders, Mr. Hairston, Commander Underwood, and the undersigned, assembled in the office of the National Hurricane Center on August 27, 1969.

The first group visited the coastal area and interviewed Weather Bureau officials, State and local Civil Defense officials, local government officials, and representatives of the news media to gather facts concerning the adequacy of the forecasts and warnings, the application of the warnings to local protection activities, and the state of community preparedness actions.

The second group visited the National Hurricane Center primarily for the purpose of gathering facts concerning the overall functioning and operations of this Center during Hurricane CAMILLE. The Director and staff of the National Hurricane Center were queried extensively concerning the problems associated with the prediction and warnings of this great hurricane. The Directors of the National Hurricane Research Laboratory, the Director of the Experimental Meteorological Laboratory and their staffs provided useful background information and facts concerning hurricane forecasting research. Finally, the Director of ESSA's Research Flight Facility provided the group with important insights into the hurricane reconnaissance problem.

It was agreed that this survey should concentrate upon the effectiveness of the meteorological service system in attacking the warning problem associated with CAMILLE. Once this was ascertained it then became possible to identify actions needed to strengthen the system.

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*Professor Sanders chose not to participate in the discussion leading to the recommendations for additional research. This is because he is presently named as the principal investigator in a research grant to Massachusetts Institute of Technology for the conduct of research related to hurricane forecast problems.

The survey team is indebted to numerous individuals within ESSA, other Federal agencies, State agencies, representatives of the news media, and the general public for their contribution to this report. It is impossible to enumerate all of them but particular credit should go to the Directors of the National Hurricane Center, the Atlantic Oceanographic and Meteorological Laboratories, and the Associate Director, Meteorological Operations of the ESSA Weather Bureau and their staffs. The survey would not have been possible without their cooperation and assistance.

D. C. House
Chief, Atmospheric Science Services Division
Office of Plans and Programs

EXECUTIVE SUMMARY

On Thursday morning, August 14, 1969, a Navy reconnaissance flight requested by ESSA's National Hurricane Center intercepted a rapidly developing depression in the Caribbean about 400 miles south of Miami. This was the beginning of one of the worst storms in North Atlantic history: CAMILLE. By Sunday night, August 17, hurricane CAMILLE had struck across the Gulf coast between New Orleans and the Florida panhandle with winds of 190 miles per hour and tides 15 to 30 feet above normal near the eye. The hurricane was the most violent of record for the United States mainland.

The hurricane warning cycle for CAMILLE began after aerial reconnaissance on August 14. Thereafter, the developing storm was kept under virtually continuous surveillance by aerial reconnaissance, environmental satellites, and, as it neared land, coastal weather radars, tide gages, and human observers. CAMILLE's point of arrival along the coast was forecast about 15 hours before the storm struck, permitting a massive evacuation of the hurricane-conscious population of that area. This 15-hour warning, taken with the high level of individual and community preparedness for such emergencies, saved an estimated 50,000 lives.

The purpose of the ESSA survey team reporting here was to evaluate the performance of the hurricane warning service and related activities during the CAMILLE emergency. To do this, the team focused on the actual warning and reconnaissance activities, and on the responses of municipal and emergency officials in the stricken area. The team's general conclusions were that:

—*The warning system performed in an outstanding manner.*

—*The accuracy of hurricane prediction and warnings compares favorably with the present state of meteorological science and our present understanding of hurricanes.*

—*The strong cooperation between Federal, State, and local authorities, the news media, and the public, together with community preparedness, accounted in large part for the saving of lives along the Gulf coast.*

CAMILLE did reveal some defects in the hurricane warning system, and pointed up the need to advance the state of the science and supporting technology.

Specifically, the survey team recommended that:

—*positive action be taken to ensure the maintenance of community action plans where they now exist, with the ESSA Weather Bureau taking the lead in helping coastal communities develop plans where no preparedness plan existed before.*

—the VHF-FM Weather Broadcasts, an extremely effective means of communicating with the general public and responsible authority, be installed on the Gulf and Atlantic coasts.

—the installation of urgently needed emergency power generators be accelerated at all locations responsible for warning dissemination.

—immediate action be taken to replace the facilities and equipment damaged or destroyed by CAMILLE, and that:

- *observing equipment be installed on at least five additional offshore oil platforms in the Gulf of Mexico;*
- *at least 14 new Cooperative Hurricane Reporting Network (CHURN) stations be established at Coast Guard stations and marinas along the Gulf and Atlantic coasts;*
- *the cooperating merchant ship observational program be expanded;*
- *the continuous-reading tide-gage program be expanded to improve real-time observation of tidal levels; and*
- *the worn out and obsolete equipment used in the Bahamas, St. Kitts, St. Lucia, and Dominica be replaced.*

—immediate action be taken to restore the Boothville Weather Station and to provide assistance to the Caribbean and Latin American countries to update their upper-air facilities.

—the frequency of upper-air observations at Vera Cruz, Mazatlan, Mexico City, St. Maarten, Trinidad, and Barbados be increased to two per day.

—the obsolete radar equipment at San Juan, Puerto Rico, which occupies a key location in the Tropics, be replaced by a modern radar as soon as possible.

—installation of remote readouts at nearby Weather Bureau offices from existing Weather Radar offices along the Gulf and Atlantic coasts proceed as planned.

—data from the existing Applications Technology Satellite series be made available to the hurricane warning service on a real-time basis until the Geostationary Operational Environmental Satellite system enters service.

—the Director of the National Hurricane Center specify the details of his requirements for altitudes of hurricane penetration and these be included in the Plan of the Day.

—action be undertaken leading to improvement in the aircraft and sensory equipment used in aerial reconnaissance. (A special analysis of hurricane reconnaissance is being undertaken by the Federal Coordinator for Meteorological Services and separate recommendations on this phase of the hurricane tracking problem will be made.)

—the Department of Transportation's Federal Aviation Administration be apprised of the impact of any loss or delay of information used in issuing hurricane warnings.

—a comparative study be made of existing high-frequency radio, satellite microwave, and other communications systems to determine the best system for use in hurricane emergencies.

—a major research and development program be mounted with principal attention given to improvements in operational hurricane forecasting. Such an effort should include the development of improved tropical analysis technique using low-level winds derived from synchronous satellite data and the development of better numerical prediction models.

—ESSA set a goal of reducing the displacement error (between predicted and observed position) to the order of 75 miles in 24 hours by 1974.

In considering priorities of the actions recommended above the survey team further recommended that highest priority be given to the following:

1. *Public education and community preparedness programs.*

2. *Improved aircraft reconnaissance.*

3. *Safe quarters and reliable power and communication facilities.*

4. *Forecasting research and technique development based upon new technologies, to be accelerated as we approach a minimum standard of preparedness and public awareness of the consequences of a failure to respond to hurricane warnings.*

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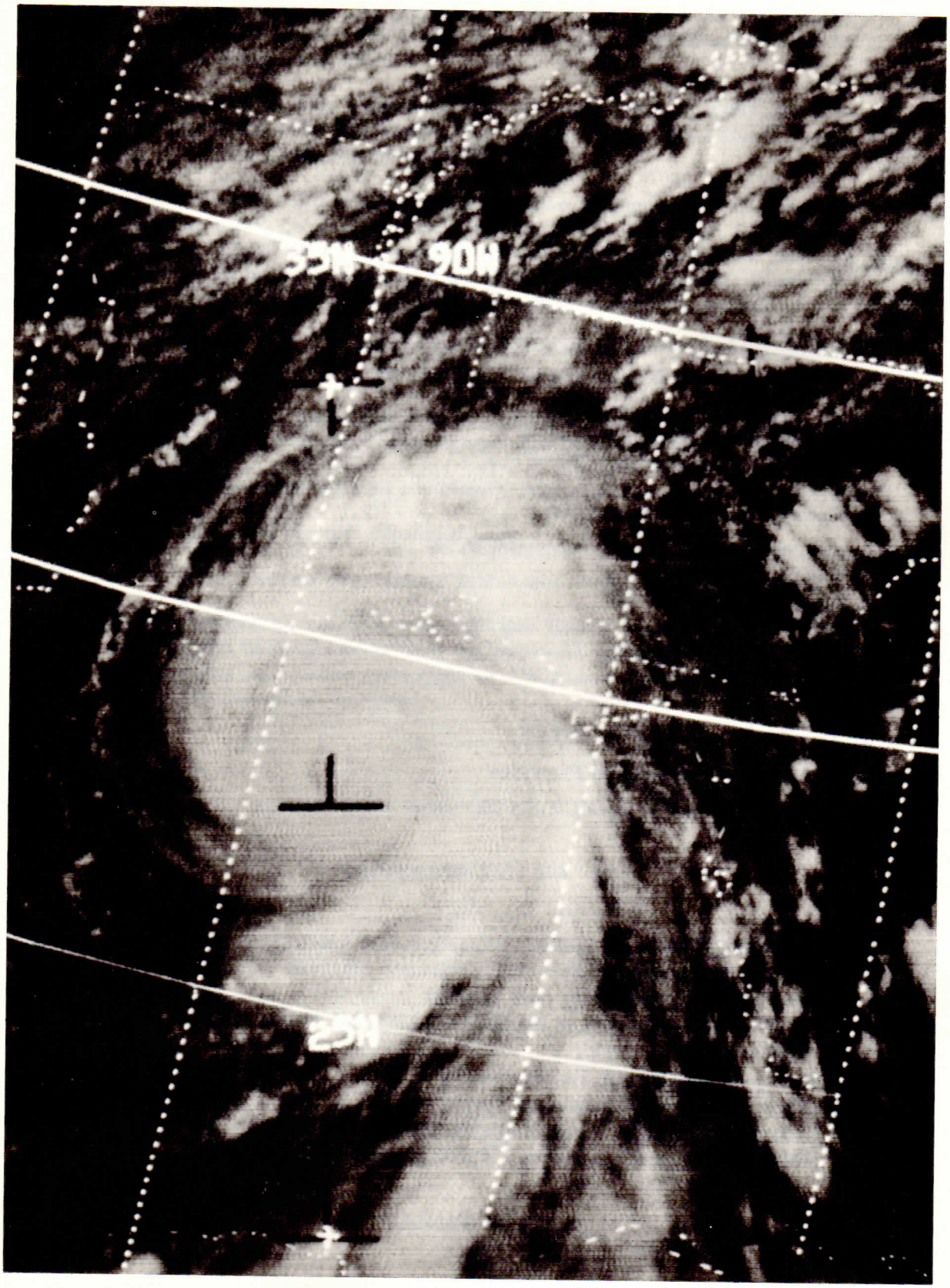


Hurricane CAMILLE, photographed by ESSA 9 cameras at 3:57 pm EDT, August 17, 1969, as the violent storm approached the U.S. Gulf coast.

Chapter I

Hurricane CAMILLE

On Thursday morning, August 14, 1969, Navy 7, a reconnaissance plane out of Jacksonville, was flying a weather mission over the Caribbean. The flight had been requested by the National Hurricane Center in Miami to investigate a suspicious low pressure tropical wave which had moved across the Atlantic from Africa and ranged across Cuba into the western Caribbean.

Four hundred eight miles south of Miami and 60 miles west of Grand Cayman Island Navy 7's flight pattern intercepted a rapidly developing depression which grew with amazing speed and reached storm intensity even as the aircraft circled the area. Running low on fuel, Navy 7 reported data on the storm location near Latitude 19.3 north and Longitude 82.3 west—maximum surface winds over 57 miles an hour, sea-level pressure 29.49 inches—and headed for home. Navy 7 had witnessed the birth of one of the most vicious storms ever recorded in North Atlantic hurricane history: CAMILLE.

Advisory Number One on CAMILLE was issued by the National Hurricane Center at 1 pm EDT that day. It reported the storm moving west-northwest at about 13 miles an hour with highest winds about 60 miles per hour in a small area near the center. It was predicted to reach the extreme west tip of Cuba by early the following morning, raking the Isle of Pines with gale force winds in its passage. Significantly, this first advisory on CAMILLE prophesied: "conditions favor rapid intensification of this young storm."

Two advisories and two bulletins were to follow that day, the beginnings of a constant flow that were to report on CAMILLE's every movement as her threat intensified.

Early on the morning of August 15 CAMILLE reached hurricane intensity about 60 miles south-southeast of Pinar del Rio. Cuba was warned by the National Hurricane Center to prepare for rapidly increasing winds reaching hurricane force by early afternoon with tides up to eight feet on the southwest coast. Cuban radar had the storm under surveillance, and radar reports from Havana were relayed as CAMILLE edged closer on a northwesterly track.

Although still maturing, winds at the storm's core had already reach 115 miles an hour on the afternoon of the 15th, and the central pressure had dropped to 29.40 inches. A bulletin issued at 3 pm on August 15 distinguished her as the most intense hurricane since BEULAH of 1967.

CAMILLE moved across western Cuba on the evening of the 15th and was off the northern coast before the day was through. In the vicinity of Guane and the Isle of Pines, 90-mile-an-hour winds and 10-inch rains were reported.

Weakened only slightly by her trek overland, CAMILLE began to regain her strength over the warm waters of the Gulf of Mexico. Radar and plane surveillance placed her early Saturday at Latitude 23.2 north and Longitude 85.0 west or about 220 miles west-southwest of Key West moving north-northwest at 10 miles an hour with winds estimated at 100 miles an hour near the center.

At 9 am CDT, Saturday, August 16, Special Advisory Number Nine set up a Hurricane Watch from Biloxi, Mississippi, to St. Marks, Florida, and warned that CAMILLE was "potentially a very dangerous hurricane," with winds expected to remain at not less than 100 miles an hour, and a strong possibility of further intensification. At 11 am the same day hurricane warnings were issued for the area from Ft. Walton to St. Marks, Florida, and preparations were urged for tides of five to ten feet.

The Southern Regional Office, Weather Bureau, moved to assign a special crew to reopen a Weather Bureau office at Pensacola, Florida, and provide additional protection for that area of the coastline.

Late Saturday afternoon, Reconnaissance

Group aircraft found the storm had slowed but deepened rapidly. Maximum winds were estimated at 150 miles per hour near the center, which was located about 380 miles south of Ft. Walton.

At 7 pm Saturday, August 16, a bulletin identified hurricane CAMILLE as a "very intense and dangerous storm" and raised tide estimates to 12 feet. Later that evening CAMILLE resumed her north-northwest movement at about 12 miles per hour. She was generating winds of 160 miles per hour near her center with hurricane-force winds extending 50 miles in all directions.

On Sunday, August 17th, with "extremely dangerous" CAMILLE 250 miles south of Mobile, Alabama, Advisory Number Thirteen was issued at 5 am CDT extending hurricane warnings westward to Biloxi, Mississippi, and a hurricane watch was moved west to New Orleans and Grand Isle, Louisiana.

Weather Bureau staffs, maintaining an all-night vigil, alerted their communities, now affected by the watch and the warnings, and the tempo of preparation quickened.

Some residents along the Gulf Coast had already begun boarding up homes and businesses in the early hours of that Sunday morning, and a trickle of cars moved on the highways leading north as dawn approached.

Four hours later, at 9 am Sunday, with CAMILLE about 200 miles southeast of New Orleans, Advisory Number Fourteen issued warnings for all the Mississippi coast and the hurricane watch was changed to a warning as far west as New Orleans and Grand Isle. The advisory forecast hurricane-force winds from extreme northwest Florida to southeast Louisiana by late afternoon or early evening with tides up to 15 feet near the center. "Present indications are that the center of CAMILLE will pass close to the mouth of the Mississippi River late this afternoon and move inland on the Mississippi coast tonight."

Preparations for the storm reached a crescendo. The stream of evacuees became a flood as the threat to the low-lying coastline became evident. People hastily loaded what few belongings they could carry with them and fled. Local officials appeared on radio and television stations to point out the danger and plead with those who were reluctant to abandon their homes. Police and Civil Defense officials went through the areas of special hazard to contact individually those who thought they could "last it out."

At 1 pm Sunday a bulletin issued from the Weather Bureau Forecast Center in New Orleans forecast the possibility of tornadoes associated with CAMILLE, but it was at 3 pm that the full extent of the danger was realized. Air Force reconnaissance reports early Sunday afternoon indicated a central pressure in CAMILLE of 26.61 inches, the second lowest on record, and maximum winds were estimated at 190 miles per hour near the center. Tides up to 20 feet above normal were forecast from Gulfport to Pascagoula in the 3 pm Special Advisory, with 10-to-15-foot tides in the area between Pascagoula and Mobile.

No hurricane as intense as this had ever struck the mainland of the United States. The need to remove everyone from the tidal beaches was urgent and, in at least one case, arrests were made in a desperate move to save lives. By official estimate 81,000 people moved to safety. The remainder were fully warned but some stubbornly remained: the curious, the unbelievers, the survivors of past storms, and those few who could not bring themselves to abandon all they owned.

By 7 pm Sunday, the Weather Bureau Office at Boothville, Louisiana—about 60 miles southeast of New Orleans—was reporting wind gusts of 107 miles per hour. An offshore drilling rig was raked by gusts estimated to be about 170 miles per hour. On the Mississippi shore as the evening progressed the wind increased until by 10 pm its sound was a continuous roar. In the unbelievable chaos of windblown debris, the dreadful tide moved on the land. Sweeping inshore it was an irresistible force topped by crashing waves that demolished everything in its path. Ocean-going vessels and small craft alike were swept inland and deposited among the remnants of buildings. Eyewitnesses reported that the deluge remained ashore very briefly—only for some 20-30 minutes—sucking back into the Gulf of Mexico with such speed that it carried much of its appalling burden with it.

The eye of CAMILLE moved inland just east of Bay St. Louis, Mississippi, about 11:30 pm that night. It has been estimated that gusts of

at least 190 miles per hour hit the city, while winds of 150 miles per hour or more raked the area east of Biloxi. In Bay St. Louis and tiny Pass Christian electrical fires raged unchecked during the storm. At a NASA site near Picayune wind velocities up to 160 miles per hour were recorded. Tides ranged 15 to 30 feet above normal just east of the eye and up to five feet above normal as far east as Apalachicola, Florida.

On Monday morning the sun was out hot and clear, a familiar Gulf coast summer day. Survivors emerged from their shelters in shock and looked at the incredible desolation left by the storm.

In Louisiana's lower Plaquemines Parish a massive tide surge over the Mississippi River levees had removed almost all traces of civilization.

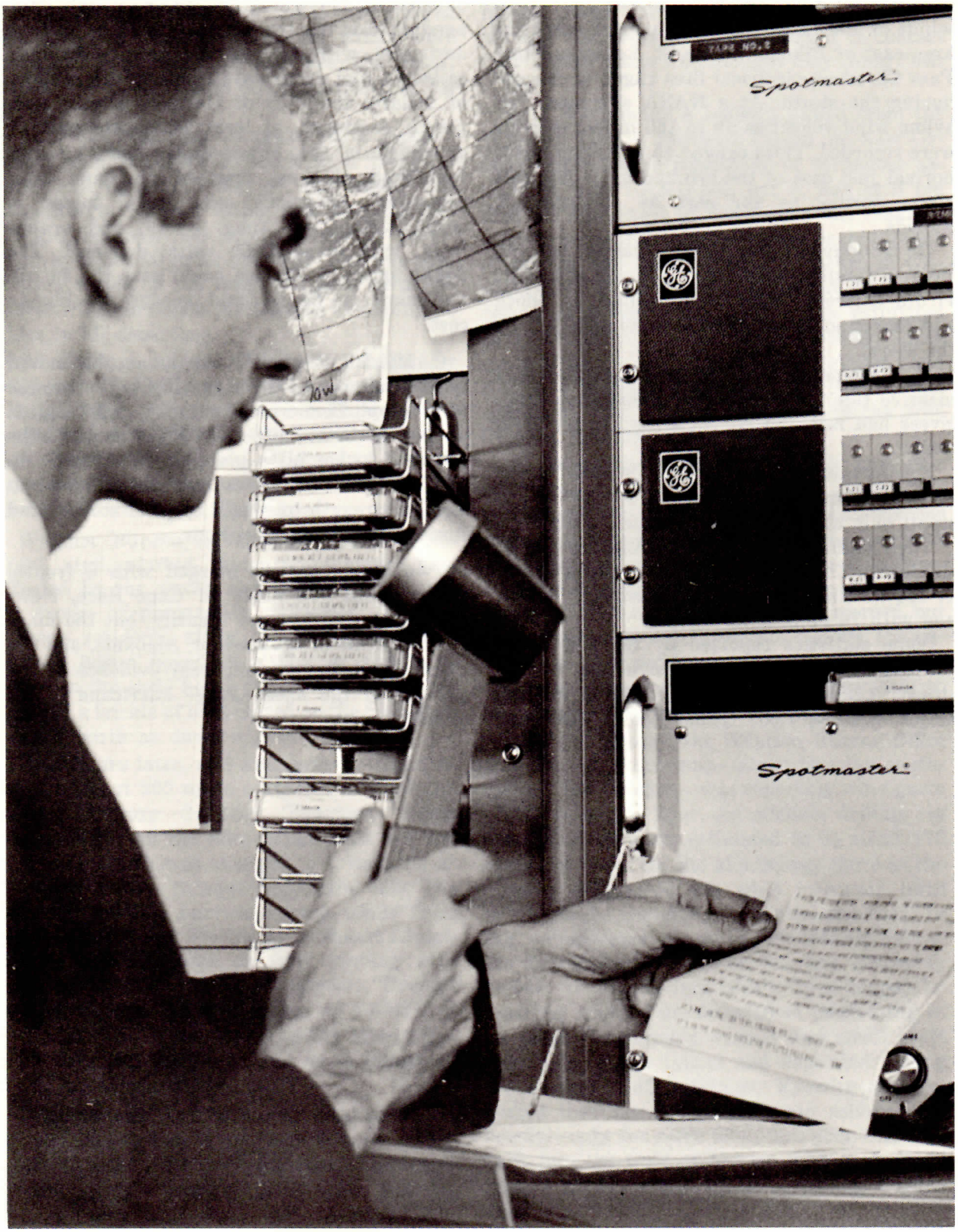
Six-thousand persons had made their homes in the community of Buras along the Mississippi; only six structures remained standing.

Then begun the task of counting the cost of the storm. The death toll at this writing stands at 140 in Mississippi and southeastern Louisiana with 76 persons missing.

Some statistics reported by the Red Cross provide evidence of the destruction of the storm: 5,238 homes destroyed, 11,667 suffered major damage; 1,007 trailer homes, 569 small businesses, 32 boats destroyed or severely damaged; at least five trucking terminals completely destroyed, with damage to highways, bridges, railways, and waterways running into millions of dollars; the Port of Gulfport almost completely destroyed, at least 94 vessels sunk or grounded in the Mississippi River; oil rigs foundered, pipelines smashed, and land bases destroyed; enormous agricultural losses in crops, timberland, tung, pecan, and orange trees, with some 5,000 cattle drowned. The dollar figure in damage could pass the $1 billion mark; no figure could measure the human cost.

CAMILLE weakened slowly as she moved inland and moved on a curving path through Mississippi, Tennessee, Kentucky, and Virginia during the 18th, 19th, and 20th of August. She returned to her birth place in the Atlantic on the 20th, and still was able to summon up enough strength to regain tropical storm wind forces of 65-70 miles per hour.

Two days later she merged with a frontal system some 175 miles off Cape Race, Newfoundland, and lost her identity, but the mangled coastline of Mississippi, Alabama, and the Louisiana delta will long bear evidence of the passage of the most savage hurricane in recorded history.



The ESSA Weather Bureau's VHF-FM continuous weather broadcast service was found to be "an extremely effective means of communicating with the general public and responsible authority" during hurricane emergencies.

Chapter II

Preparation and Warnings

A. The Hurricane Warning Service

The objectives of the Hurricane Warning Service of ESSA Weather Bureau are to save lives and to minimize loss of property by timely and effective alerting of the public of the location and movement of hurricanes. The policy underlying this program is the provision by ESSA of a single national authoritative source for the provision of forecasts and warnings of extremely hazardous meteorological events.

In the Hurricane Warning Service, seven ESSA Weather Bureau offices maintain a close watch on the areas of potential or incipient tropical cyclones and produce and issue advisories and bulletins for the public, disaster and rescue agencies, and salvage workers in threatened areas. These include the National Hurricane Center in Miami, forecast and warning offices in San Francisco and Honolulu, and warning offices in Boston, Washington, D.C., New Orleans, and San Juan.

The National Hurricane Center provides a single source for hurricane forecasts in the Atlantic and Gulf Coast areas and is responsible for technical matters pertaining to the Atlantic Hurricane Warning Service, including the supervision of warnings prepared at Boston, Washington, D.C., New Orleans, and San Juan.

The hurricane advisories and bulletins prepared by the warning offices for the public contain the position, intensity, direction and rate of movement, areas under watch and warnings, and include a statement of the effects to be experienced from the storm, including prediction of wind-driven tides (storm tide), strength of winds expected on the coast, and amount of rainfall.

The Weather Bureau is also directed to study fully the internal structures of hurricanes. Research and development activities are conducted on hurricanes and other tropical circulations to acquire increased knowledge of these storms and to apply this knowledge to improvement of techniques of storm detection, forecasting and warning, and to development of possible means of storm modification. The focal point for ESSA research and development activities on hurricane research is the National Hurricane Research Laboratory at Miami, Florida. Also in Miami is the Research Flight Facility. The Facility uses four ESSA-owned aircraft: two DC-6's, one B-57, and one DC-4. The two DC-6 aircraft are specially instrumented as flying laboratories to penetrate hurricanes.

B. Community Preparedness Plans

Planning for effective community action in a hurricane emergency is a major concern of ESSA Weather Bureau offices.

Before the commencement of the hurricane season (June 1 through November 30) the Officer in Charge of Weather Bureau Offices responsible for issuing forecasts and warnings for cities and communities along the Gulf of Mexico and Atlantic Ocean Coasts vulnerable to hurricanes holds a Hurricane Preparedness Conference. The objective is to alert people *to the dangers of hurricanes and to help communities develop community hurricane preparedness plans or to check on plans already formulated.*

Invited to the conference are the mayor, Civil Defense, American Red Cross, police, city engineer, superintendent of public works, superintendent of street department, superintendent of schools, newspaper, radio and television representatives, power and gas company officials, manager of transit system, harbor police, and port authorities.

Preceding the hurricane season of 1969, 30 such conferences were held in Atlantic and Gulf coast cities, ranging from Portland, Maine, to Brownsville, Texas.

Copies of an ESSA pamphlet, *A Model Hurricane Plan for a Coastal Community,* are provided to local authorities at the conferences. The plan offers suggestions as to planning and organization to minimize hurricane losses. In 1969, 2,800 copies of the plan were distributed. In many cities the pamphlet is used as the basis

for a detailed local Civil Defense Emergency Plan with great effectiveness.

In addition to the *Model Plan* the following informational brochures were distributed in 1969, in the quantities shown:

Hurricane, a 40-page booklet giving information on hurricanes; *18,000.*

Hurricane Information and Atlantic Tracking Chart, a fanfold explaining hurricanes; *84,400.*

Some Devastating North Atlantic Hurricanes of the 20th Century, a 10-page pamphlet with tracks, damages, and casualties; *10,000.*

Hurricane/Storm Surge Safety Rules, a poster with information on things to know about hurricane and storm surges; *72,500.*

A public information campaign on hurricanes, offering ad mats, was run in May 1969 as well as a hurricane campaign to Bell System outlets offering copy, artwork, and photos for use in billing inserts. On June 5, 1969, the 30-minute color film *HURRICANE!* was released for use on all coastal television stations for public service programming, with a reported total to date of over 2 million viewers.

Leadership in preparation for hurricane emergencies must come principally from local authorities. They direct municipal and community planning, control most of the facilities which would be used in meeting an emergency, possess the necessary detailed knowledge of the local area, and have the immediate responsibility for the welfare of their community and its residents.

A permanent Hurricane Preparedness Committee is organized to provide the coastal city and suburban communities with adequate protection to minimize the deaths and property losses usually associated with hurricanes. The Committee directs a program designed to educate the public on the hazards of hurricanes and the protective measures to be effected. It makes recommendations regarding construction projects and changes in building codes required to lessen danger and destruction from hurricanes. The American Red Cross member of the Committee designates buildings to be used as shelters. The City Engineer prepares maps showing locations of shelters, emergency bus loading points, and evacuation routes. These maps are printed and distributed to all residents of the area. Additional copies are distributed every June.

Radio and television stations are requested to present in late May or early June of each year a series of at least five 15-minute broadcast interviews with authorities on various phases of hurricane preparedness. The superintendent of schools is directed to instruct his teachers to inform their charges of these radio and television broadcasts and to quiz them on the information broadcast. Newspapers are encouraged to publicize these broadcasts and publish summarizations of the interviews. The broadcasts and newspaper articles include mention of continual precautionary measures that tend to reduce danger and damage during an emergency and give instructions on what should be done when a hurricane is expected to strike the area.

When a hurricane watch is issued for the area, the local Weather Bureau office immediately notifies the chairman of the Hurricane Preparedness Committee. The chairman calls an immediate meeting of his Committee to review preparations for emergency procedures. The fire and police departments place all their personnel on 24-hour on-call duty. American Red Cross calls for additional personnel and equipment. State police set up check points on main highways leading into the threatened area to control entry and re-entry. The county sheriff sends his force out to alert all exposed settlements and trailer camps to maintain a constant radio watch for further instructions. Also, they are informed where to go if they are warned to evacuate.

When a hurricane warning is issued for the area, emergency procedures are initiated. Although the Weather Bureau has no authority to order evacuation, it is the agency to which the general public and responsible public officials must look for recommendations on evacuation. Since advisories and bulletins from hurricane warning offices must be reasonably short, evacuation recommendations are included only in broad terms. More specific information is contained in hurricane statements issued by local Weather Bureau offices. The final authority for execution of evacuation plans in the city is the mayor and in the county it is the county director of Civil Defense.

Local governments representing the larger segments of population along the Gulf coast,

Pascagoula, have prepared and printed emergency action plans containing the essentials of the "Model Hurricane Action Plan." These have been distributed to all people with particular responsibilities in the plan and in some cases were available to the news media as information to broadcast. The focal point for community preparedness action in the Alabama, Mississippi, Louisiana areas was generally the local Civil Defense unit in the centers of larger population or the police office in smaller communities.

Weather Bureau officials from New Orleans such as New Orleans, Mobile, Gulfport, and Mobile, the offices serving the Gulf coast area most affected by hurricane CAMILLE, had attended biennial preparedness meetings sponsored by four of the larger Civil Defense agencies. All smaller Civil Defense units and police from surrounding areas also were invited to attend. Weather related problems and preparedness actions to combat them were discussed extensively. At least once annually the officials in charge of local Civil Defense and community preparedness are visited individually by Meteorologists-in-Charge of nearby Weather Bureau offices. The New Orleans office uses its VHF equipment effectively to broadcast weather information, but the Mobile Weather Bureau must place heavy dependence for providing weather information for dissemination by radio and television stations in the Mobile area on a direct wire Emergency Broadcast System (EBS) which is a land-line circuit with two-way capability between Weather Bureau and Civil Defense offices and one-way to five radio and TV stations. Of the four remaining non-participating stations in the Mobile area, one—WALA-TV—depends on ESSA Weather Wire service. Mobile newspapers are served by national wire services or through telephone contact. In the Mississippi coastal area of responsibility only two stations—WLOX-TV Biloxi and WGCM Gulfport—subscribe to the ESSA Weather Wire service. All other mass media in the area obtain their weather information from UPI and/or AP wire service. Direct contact with the Weather Bureau in Mobile is made by telephone.

C. Specific Action

Because of Hurricane CAMILLE's early threat to the Florida coastline the former Weather Bureau Office at Pensacola was reopened on August 15. This action was part of the preparations made by the Weather Bureau to place all its facilities in a full state of readiness.

As a backup to tracking of the hurricane by land based radar, the Weather Bureau assigned a man to use the military radar at Tyndall Air Force Base, Panama City, Florida, on August 15. Also, on August 15 an electronic technician was dispatched to help at Weather Bureau Office Key West, Florida.

Weather Bureau personnel were detailed from Weather Bureau headquarters in Washington, D. C., the Southern Regional headquarters in Fort Worth, Texas, or other duty stations to provide specialized assistance at seven different Weather Bureau offices along the east and Gulf coasts between August 14th and 17th. As the warnings were moved westward personnel were shifted to cover the new area of concern.

At the suggestion of Weather Bureau Forecast Office New Orleans, a statement was issued by Weather Bureau Office Mobile, at about 5 am on August 17, advising the evacuation of the low-lying areas from Bay St. Louis, Mississippi, to Mobile, Alabama.

Telephone contact was made immediately by the Mobile Weather Bureau Airport Station to WLOX-TV in Biloxi, and to Civil Defense Directors in Pascagoula, Biloxi, and Gulfport, putting them on full alert. The warning was then relayed by Civil Defense to all radio stations in the area, and broadcasting of the Weather Bureau advisories and bulletins and local emergency information became continuous.

Similar statements were issued almost simultaneously from Weather Bureau Forecast Office New Orleans covering the low-lying areas from Bay St. Louis to Grand Isle, Louisiana. These statements reached all Civil Defense and police officials in the affected areas almost immediately. This was about 12 hours prior to winds of any consequence being reported along the coast.

By 9:30 am the Hurricane Emergency Information Center in Mobile was staffed by an Information Officer from ESSA headquarters in Washington, to assist in the flow of news between the Weather Bureau and the media for the duration of the emergency.

VHF radio in New Orleans, the Emergency Broadcast System in Mobile and the ESSA Weather Wire provided continuous service of hurricane information. Press wire service was covered by UPI in the Mobile Weather Bureau Office. The AP was represented in the Mobile *Press-Register* office.

During the morning hours of Sunday, August 17, officials briefed other local government officials on the hurricane warnings. Evacuation of areas below 20 feet elevation was begun immediately in some cases, but was delayed until early afternoon in one case. Through contact with the President of the Parish Council, evacuation of low areas in Plaquemines Parish was begun as early as Saturday since their experience with hurricane BETSY was still a vivid memory. Four persons, however, hid to avoid evacuation. One was rescued, the other three perished. Fishing and boating camps along Lakes Pontchartrain, Catherine, and Borgue were also alerted and emptied. Officials estimate that 12,000 persons were moved out of Plaquemines Parish, Louisiana.

Along the Mississippi Gulf coast, police and Civil Defense and volunteers made heroic efforts to warn and remove people. These efforts continued until rising tides and wind made it impossible to move about.

Radio and television stations in Gulfport, Biloxi, and Pascagoula remained on the air broadcasting a steady flow of storm information, urgent pleas from local officials for evacuation from critical areas, and bulletins from local emergency sources until power was lost or the station was destroyed.

It has been estimated by Civil Defense officials that 99 percent of the people living below 20 feet elevation along the Mississippi Gulf coast were evacuated and the remainder were fully warned, but chose to "ride out the storm" for one reason or another. Some were forcibly removed from their homes by police. In one known case, a group of 34 people who were definitely warned perished and in another a party of 23 were lost. Four people died in Jackson County, 3 in Plaquemines Parish, and the total will probably approach 200 in Harrison County.

In statements made by Captain Howard T. Black, Head, Mobile Civil Defense; Warren R. Bosworth, Head, Pascagoula Civil Defense; Mrs. Julia Guice, Head, Biloxi Civil Defense; and Wade Guice, Head, Harrison County, Mississippi, Civil Defense—it was estimated that 2,000 people were evacuated in Mobile County, Alabama; 26,000 in Jackson County, Mississippi; 41,000 in Harrison County (including 25,000 moving to shelters at Keesler Air Force Base) in the area where storm damage was the greatest.

Since it is almost a certainty that a majority of people remaining in the low-lying areas would have been lost, one can assume that at least 50,000 people were probably saved by the combined efforts of the Weather Bureau, Civil Defense, and police as well as news media. All Civil Defense officials contacted firmly believe, without exception, that the timeliness and content of Weather Bureau warnings were excellent and responsible for saving many, many lives.

It can be said that the greatest problem in warning of Great Hurricane CAMILLE was disbelief. The people could not relate the awesome power of this storm to anything in their experience. Winds of 190 miles per hour or more, and tides of 20 feet or more, were beyond the limits of credulity.

Regardless of the careful planning and foresight which had gone into preparing the communities for action, regardless of the warnings which gave more than 12 hours in which to reach safety, repeated visits by police and Civil Defense workers were needed to convince the tardy or the stubborn of their danger. No one with a true understanding of the situation would have chosen to remain, yet there are tragic instances of those who did.

D. Findings and Recommendations

The Task Group finds that the warnings were timely and better than the average in accuracy. There is no question that greater advanced warning would have been valuable.

Hurricane CAMILLE, probably the most vicious storm to strike the United States, was relatively small, with hurricane-force winds covering a circular area only about 175 miles in diameter. This allowed land-line communications to function almost until the storm was upon the area along the Gulf coast which was eventually severely damaged.

All communication equipment except as noted below operated without interruption before and during the storm at all ESSA facilities. Two principal weather data distribution systems were out from 9:20 pm CDT August 17 until 8 am CDT August 18 at Mobile, Alabama. There was a power outage at Mobile from 9:35 am CDT August 18 until 10:20 am CDT August 18. Weather Bureau Meteorological Office Boothville, Louisiana, lost land-line communications at 5 pm on August 17 and all other communications were lost permanently at 7:35 pm on August 17. Weather Bureau Office Mobile and all Civil Defense units in their area of warning responsibility went on standby emergency power during the late evening hours of August 17, prior to the storm's passage inland. Commercial power and telephone service was lost at 10:30 pm August 17 in southern Mississippi for periods of up to four days.

Weather Bureau Forecast Office New Orleans and Weather Bureau Office Mobile have State National Warning Service (NAWAS) drops. New Orleans uses this means to contact Civil Defense in New Orleans. Mobile uses this as backup to ESSA Weather Wire and Emergency Broadcast System. Montgomery NAWAS Control can patch through from Alabama NAWAS to Mississippi NAWAS Control in Jackson, Mississippi, for relay of information to Mississippi Civil Defense units in Mobile County warning responsibility area. This was not needed for this storm. Weather Bureau Office Jackson, Mississippi, did give weather information over Mississippi NAWAS routinely.

VHF radio was used by Weather Bureau Forecast Office New Orleans very effectively during the storm to feed continuous flow of weather information to people within a 25-mile radius of New Orleans city center. Many rebroadcasts were made of this information by other radio stations. Better VHF coverage is a must in many Gulf coastal areas in order to get warnings directly to the public as quickly as possible and in their original form.

ESSA Weather Wire was the principal means of relaying weather information to Civil Defense, radio and TV, and police officials in Mobile and in Louisiana. It was available as backup at one Civil Defense agency in Mississippi (by telephone relay from another subscriber). The ESSA Weather Wire tariff charges in some areas are more expensive than some potential subscribers can afford. This is particularly true in smaller communities.

Public telephone was relied on for communication between Weather Bureau Office Mobile and Civil Defense agencies and broadcasters in southern Mississippi. Circuit overloading caused temporary outages, especially as the storm approached the coast. Busy telephones were frequently a problem. Telephone lines were lost entirely in southern Mississippi when the storm was very near the coast.

Amateur radio operators were on standby at Weather Bureau Forecast Office New Orleans and Weather Bureau Office Mobile to operate on citizen and short wave bands to Civil Defense units in the event of the loss of telephone lines. This was not required during the hurricane.

There is ample evidence of outstanding service to the coastal communities by the local radio and television stations during hurricane CAMILLE. All stations stayed on the air with a steady flow of weather information, and there was unanimous agreement by station officials that warnings were received in time to alert the communities.

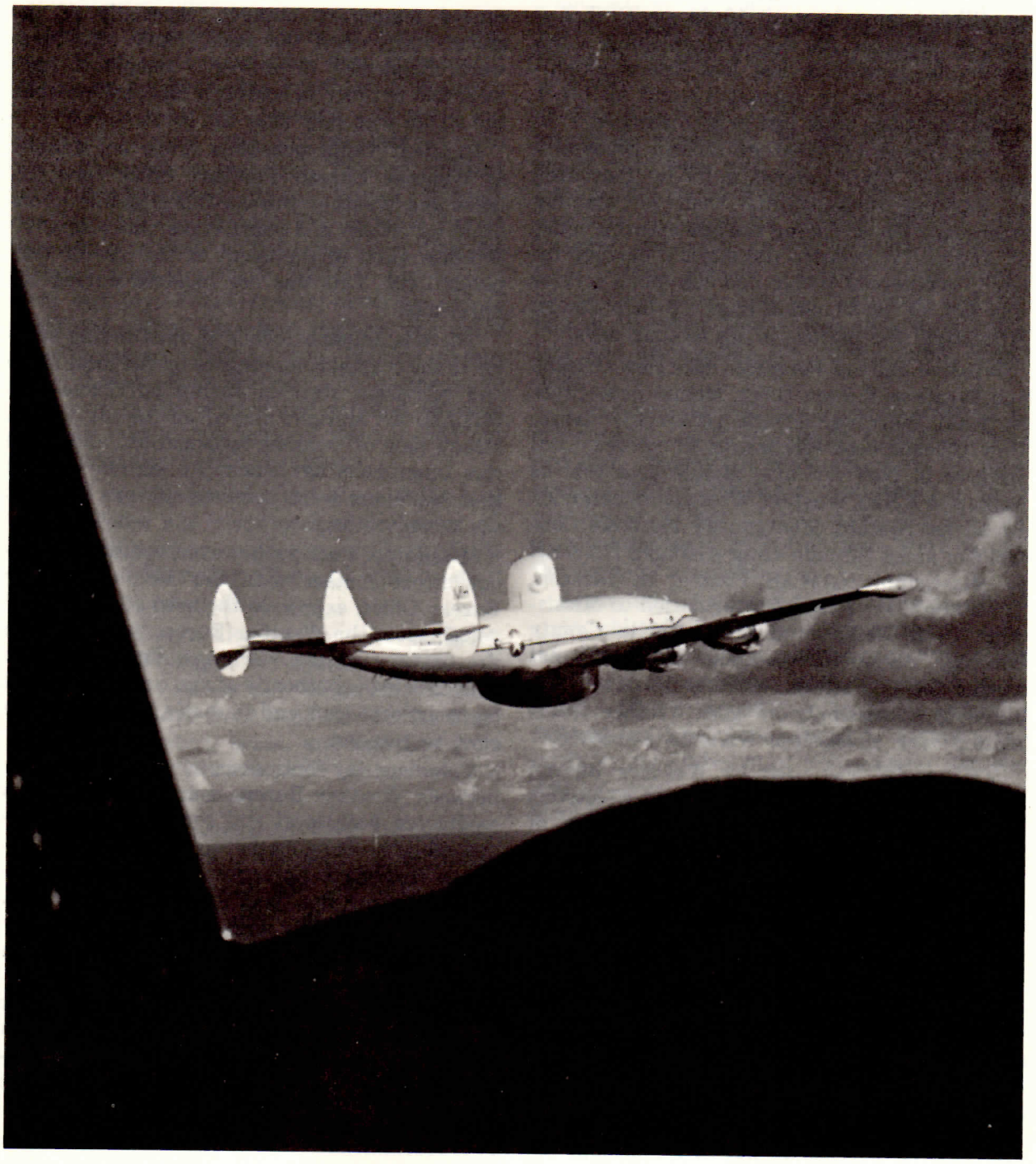
Mississippi stations, however, operating without direct contact with the Mobile Weather Bureau Office, expressed the need of an "official voice" from the Weather Bureau to emphasize the urgency of the warnings. People did not fully credit the authority of the warnings issued by their local staff and in many instances were slow to respond.

This need for continuous news dissemination between Weather Bureau offices and the mass media—in both local and remote areas of responsibility—is being met by the establishment of the Hurricane Emergency Information Center, employing the "pool" broadcast technique. Complete familiarity with the plan is necessary for coordination between radio and television stations and the Weather Bureau office in making the relatively simple installation. The task group urges that this service be kept fresh in the minds of broadcasters, by recall and explanation at annual hurricane preparedness meetings.

It is recommended that positive action be taken to ensure the maintenance of community action plans where they now exist, with the ESSA

Weather Bureau taking the lead in helping coastal communities develop plans where no preparedness plan existed before.

It is further recommended that VHF-FM Weather Broadcasts, an extremely effective means of communicating with the general public and responsible authority, be installed as planned on the Gulf and Atlantic coasts. At the same time, it is recommended that the installation of urgently needed emergency power generators be accelerated at all locations responsible for warning dissemination.



A Navy WC-121 Super Constellation of the type used for weather reconnaissance and "hurricane hunting," viewed from the cockpit of a sister ship.

Chapter III

Data Collection and Communications

A. Surface Observation Networks

The surface observing networks provide basic data for many uses and they include a variety of data collection systems which are, to the extent feasible, tailored to serve all appropriate uses. In general the networks are divided into two classes: (a) the stations that provide data for immediate use and for record purposes, and (b) the substations that provide data primarily for record purposes. Included in the substation group, class (b), are stations which also report rainfall amounts under certain conditions described below for immediate use, coastal stations, and Cooperative Hurricane Reporting Network (CHURN) stations, which report data for immediate use upon request.

The network of reporting stations (a) in the southeastern United States is shown in Figure 1. These stations are manned to provide complete surface observational data on assigned schedules. Observations taken at these stations provide a data base for all weather analysis, forecasting, warning, and weather service programs of the Nation and a significant input to the climatology of the Nation. At the present time the spacing between stations in the southeastern United States averages about 65 to 70 miles inland from the coast and about 75 to 85

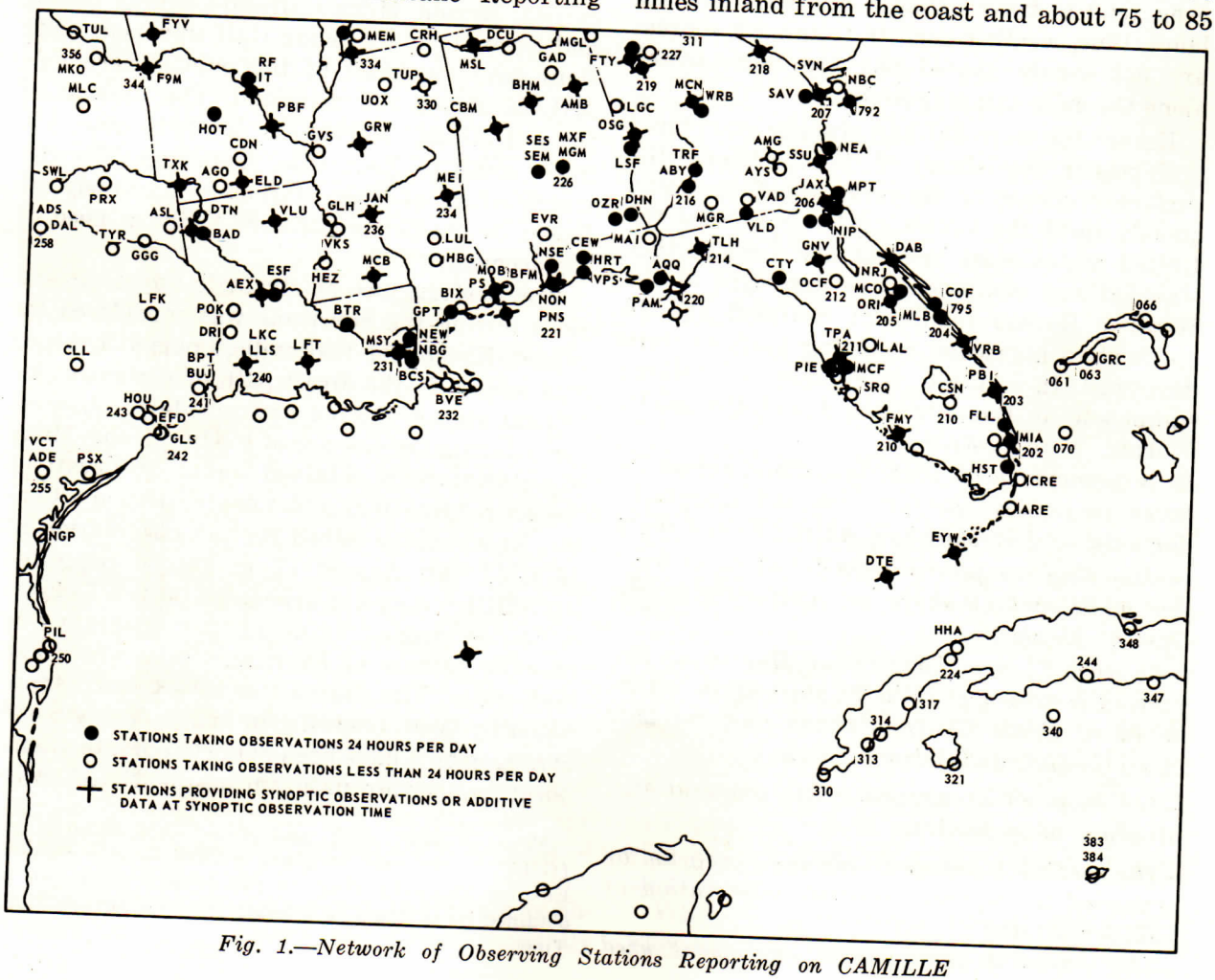


Fig. 1.—Network of Observing Stations Reporting on CAMILLE

miles in the coastal areas. To describe adequately phenomena associated with hurricane events the spacing between stations should be about 40 miles along and within 100 miles of the coasts and about 65 to 70 miles inland from the coasts.

Off-shore weather reports are obtained for immediate use from a few platforms near the shore operated by the oil industry, an automatic buoy station operated by the Navy in the Gulf of Mexico, and cooperative ships sailing through waters of the Gulf of Mexico, the Caribbean Sea, and the Atlantic Ocean. At the present time reports from the cooperative ships during daylight hours are such that if they were evenly distributed over the western Atlantic and Gulf of Mexico the spacing between reporting points would be about 110 miles. At night fewer reports are received from the cooperative ships and the average spacing becomes about 360 miles. Merchant ships, however, tend to travel along a relatively few sea lanes, thus, weather reports from such sources are not evenly spaced but are concentrated along the main shipping routes.

Except for worn-out and obsolete equipment problems in the islands of the Caribbean, the surface observation networks functioned adequately until the time CAMILLE crossed the United States coast line. At that time further observational equipment was destroyed at the Weather Bureau facility at Gulfport and 16 cooperative hurricane reporting stations were destroyed. In addition, tide gages and related equipment at Dauphin Island and Pensacola, Florida, were destroyed.

It is recommended that immediate action be taken to replace the facilities and equipment damaged or destroyed by CAMILLE, and that:

—observing equipment be installed on at least five additional off-shore oil platforms in the Gulf of Mexico;

—at least 14 new Cooperative Hurricane Reporting Network (CHURN) stations be established at Coast Guard stations and marinas along the Gulf and Atlantic coasts;

—the cooperating merchant ship observational program be expanded;

—the continuous-reading tide-gage program be expanded to improve real-time observation of tidal levels; and

—the worn-out and obsolete equipment used in the Bahamas, St. Kitts, St. Lucia, and Dominica be replaced.

B. Upper-Air Observations

Upper-air observations include measurements of pressure, temperature, water vapor, and wind direction and speed at various levels in the atmosphere from the surface up to about 100,000 feet. The primary type of upper-air observation is the *rawinsonde observation.* These are taken at 94 ESSA ground stations and 38 other cooperative and special project station locations (financed by Department of Defense), and by 15 moving ships, including merchant, Military Sea Transport Service, and ESSA Coast and Geodetic Survey vessels.

In the southeastern United States land based upper-air stations in the path of hurricane CAMILLE are spaced at intervals of 180 to 300 miles (See Figure 2). The Gulf area south of the U.S. mainland is considered a data-sparse area insofar as upper-air observations are concerned. Merida, Mexico, Grand Cayman Island, and Swan Island provide Gulf upper-air data south and southeast of the point where CAMILLE struck the mainland. The nearest of these stations, Merida, is located some 450 miles south of Boothville, Louisiana. The efficiency of all of these stations is adversely affected by obsolete equipment badly in need of replacement.

The performance of strategic upper-air stations during the hurricane was considered excellent. Except for Boothville, Louisiana, which was located in the direct path of the storm, no critical station missed any scheduled observations during the passage of the hurricane. Many of these stations obtained special observations on the request of the National Hurricane Center. Boothville obtained its last observation at 18 GMT* on August 17 (a special requested by NHC) but by the scheduled 00 GMT observation on August 18 no further program was possible because of hurricane-force winds and high water. The station was subsequently inundated by flood, resulting in heavy damage, and arrangements have been made to operate a temporary upper-air program at the NASA Mis-

*The 24-hour clock and Greenwich Mean Time (GMT) is the time standard utilized in this chapter. Eastern Standard Time on the 24-hour clock can be obtained by subtracting 5 hours from Greenwich Mean Time.

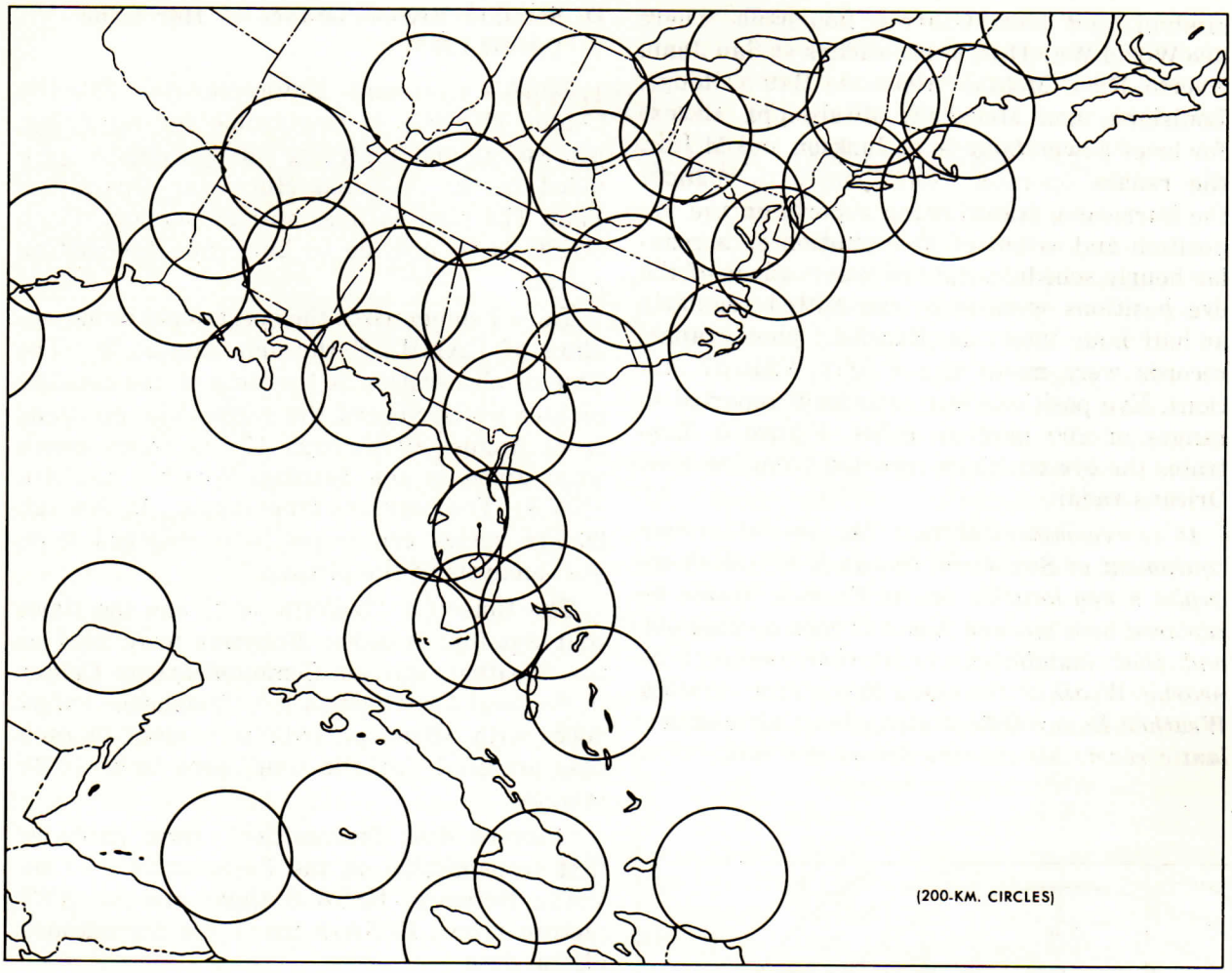


Fig. 2.—Upper-Air Coverage in Area of Hurricane CAMILLE

sissippi Test Facility until the Boothville station can be put back into operation.

It is recommended that immediate action be taken to restore the Boothville Weather Station and to provide assistance to the Caribbean and Latin American countries to update their upper-air facilities; and that the frequency of upper-air observations at Vera Cruz, Mazatlan, Mexico City, St. Maarten, Trinidad, and Barbados be increased to two per day.

C. Radar Network

Radar observations include the detection and measurement of precipitation, and identification and tracking of squall lines, hurricanes, tornadoes, and other severe storms. These observations provide systematic measurements of location, height, and intensity of precipitation, and are made hourly when precipitation is observed within the area and more frequently when conditions indicate severe storms or rapidly changing weather. Local use radar provides information for short-period forecasts and warnings in the immediate area.

The radar network includes 92 ESSA stations, of which 56 are equipped with World War II surplus radars with limited capability (local use), and 36 are equipped with modern radars (WSR–57) specifically designed for weather surveillance. These modern radars are located mainly in the tornado belt of the Midwest along the hurricane-vulnerable Gulf and Atlantic coasts. ESSA's radar network is supplemented by observations from Air Force and Navy installations which participate in an interagency Federal network designed to provide 24-hour weather radar surveillance over all critical areas of the Nation.

WSR–57 radars are located at Apalachicola, Florida, New Orleans, Louisiana, Jackson, Mis-

sissippi, and Lake Charles, Louisiana. There are World War II local use radars at San Juan, Puerto Rico, Mobile, Alabama, Baton Rouge, Louisiana, and Meridian, Mississippi. Except for brief power failures at Jackson and Mobile, the radars operated continuously throughout the hurricane, transmitting reports on the eye position and extent of precipitation on a regular hourly schedule. Special observations of the eye positions were also transmitted regularly at half hour intervals. Excellent photographic records were made at the four WSR–57 stations. Eye positions were routinely reported to ranges of 200 nautical miles. Figure 3 illustrates the eye positions reported from the New Orleans radar.

It is recommended that the obsolete radar equipment at San Juan, Puerto Rico, which occupies a key location in the Tropics, should be replaced by a modern radar as soon as possible, and that installation of remote readouts at nearby Weather Bureau offices from existing Weather Radar Offices along the Gulf and Atlantic coasts should proceed as planned.

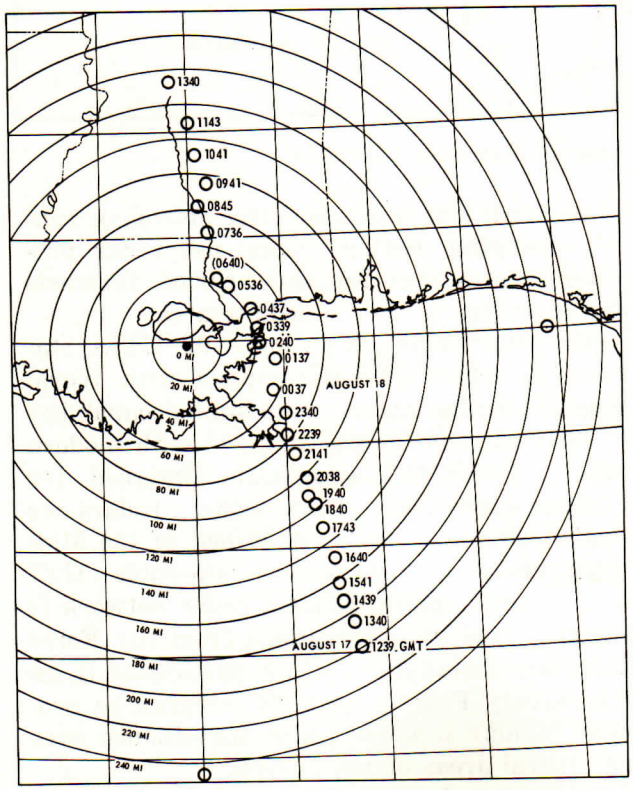


Fig. 3.—Eye Positions Reported by New Orleans

D. Satellite Reconnaissance of Hurricane CAMILLE

ESSA's National Environmental Satellite Center (NESC) is responsible for acquiring, processing, and analyzing satellite data as provided in the National Hurricane Operations Plan. The plan outlines specific support which NESC is to provide to hurricane forecasting offices.

Table I summarizes the operational data-handling of CAMILLE through August 20. The time of observation is the time of the satellite picture which viewed the storm. The positions from August 10 through 17 are those which were given in the Satellite Weather Bulletin (SWB). The positions from August 18 through 20 are vortex center positions obtained from post-analysis of the pictures.

The times for "bulletin sent" are the times that Satellite Weather Bulletins were filed at the Weather Bureau Communications Center in Suitland for transmission. Telephone conferences with Miami on bulletin content in each case preceded "bulletin sent" time by 15 to 30 minutes.

"Picture data transmitted" time indicates first transmission on the Forecast Office Facsimile Network. ESSA–8 times are for APT picture relay; ESSA–9 times are for mapped digital data.

Figure 4 contains a plot of ESSA–8 and –9 positions of CAMILLE and a preliminary plot of the storm track.

A post-analysis of the actual ESSA–8 and –9 data, which was used to prepare the Satellite Weather Bulletins, was performed by the Applications Group, NESC. This was compared with the operational interpretation. After August 14, when the storm was well organized, the average difference between the operationally arrived-at storm positions and the post-analysis positions was 18 miles. While there were some differences between the operational and post-analysis classifications and diameter measurements, the resulting differences in wind estimates were not more than ± 15 knots with an average difference of only + 1 knot. The operational interpretation of the pictures by operational personnel is therefore judged to be correct with the accuracy of the bulletin positions limited only by the gridding accuracy.

TABLE I

SUMMARY OF OPERATIONAL SATELLITE DATA-HANDLING FOR CAMILLE

1969 August Date	Time of observation	Satellite	Lat. & Long. Position	Bulletin Sent	Picture Data Transmitted
10	1847Z	E-9	15N-62W	2140Z	11/0030Z
11	1751Z	E-9	17N-65W	12/0600Z	---
12	1336Z	E-8	17N-72W	1500Z	1420Z
	1849Z	E-9	18N-72W	2300Z	12/0153Z (3)
13	0353Z	N-3	---	---	---
	1427Z	E-8	18N-78W	1530Z	1522Z
	1948Z	E-9	19N-77.5W	2210Z	Not Sent (4)
14	---	N-3	---	---	---
	1518Z	E-8	19.5N-81W	1550Z	1630Z
	1852Z	E-9	19.5N-82.5W	2240Z (2)	15/0030Z
15	0559Z	N-3	---	---	---
	1414Z	E-8	21N-84W	1450Z	1503Z
	1950Z	E-9	21.5N-84.5W	2255Z	2236Z (5)
16	0518Z	N-3	---	---	---
	1500Z	E-8	24N-86W	1620Z	1522Z
	1858Z	E-9	24.5N-87.5W	2150Z	2236Z (5)
17	0616	N-3	---	---	---
	1551Z	E-8	27.5N-88W	1635Z	1630Z
	1953Z	E-9	28N-89W	2225Z	2236Z (5)
18	0530Z	N-3	---	---	---
	1447Z	E-8	32.5N-90W	1522Z	1522Z
	1900Z	E-9	33N-90.5W	---	19/0030Z
19	0450Z	N-3	---	---	---
	1538Z	E-8	37.5N-86W	---	1630Z
	1946Z	E-9	37N-84W	---	20/0030Z
20	0553Z	N-3	---	---	---
	1435Z	E-8	38N-78W	---	1522Z
	1850Z	E-9	37N-76W	---	21/0030Z

Note: All times are Greenwich Mean Time.

(1) Position and description given in Remarks Section of "Satellite Tropical Disturbance Summary," a daily scheduled transmission at 0600Z.

(2) Bulletin excessively delayed due to photo-processing equipment breakdown.

(3) Delayed FAX transmission. Computer outage.

(4) Line outage, Gilmore Creek to Suitland.

(5) Special transmission 1:7,000,000 scale digitally mapped picture centered on CAMILLE.

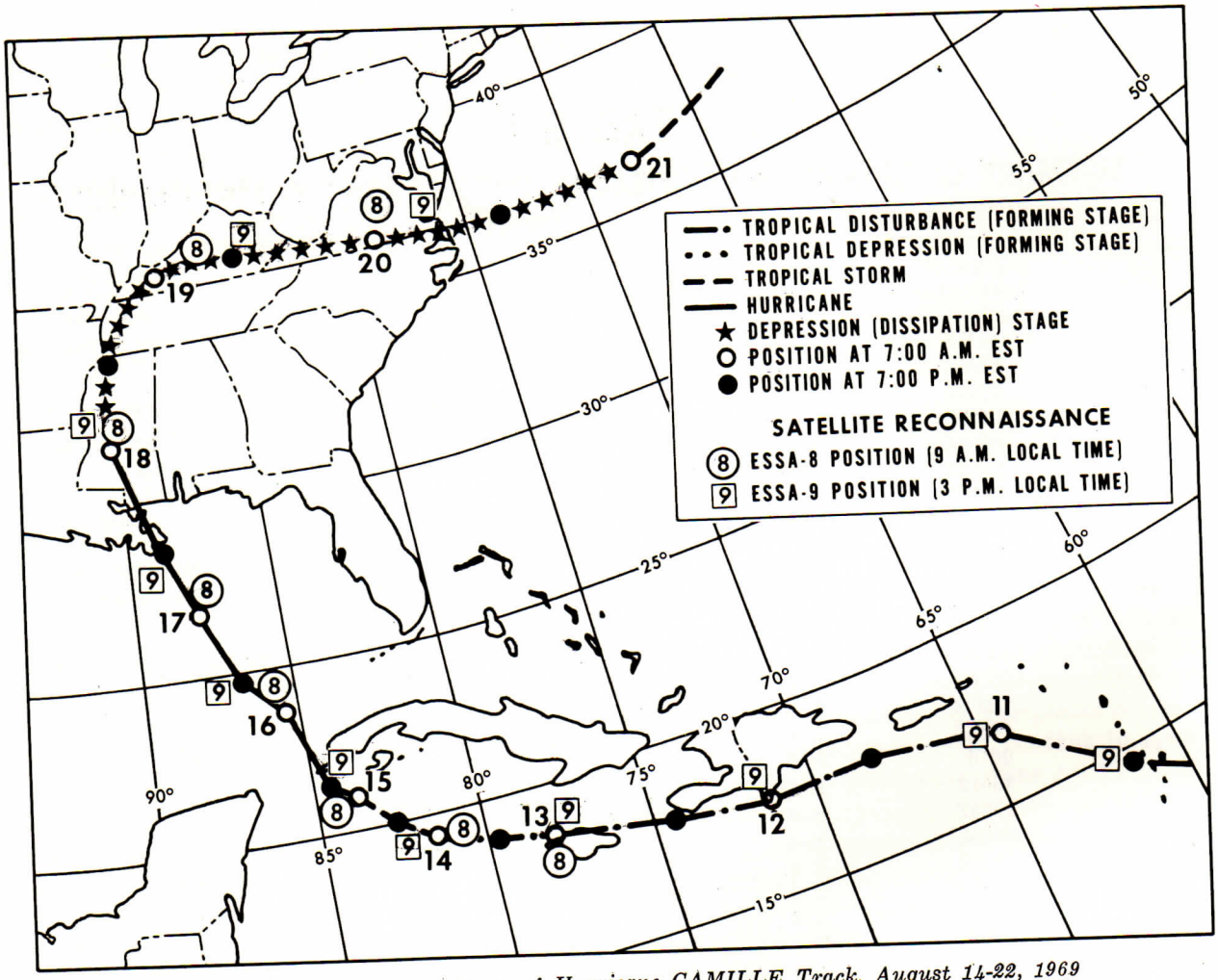


Fig. 4.—Satellite Reconnaissance of Hurricane CAMILLE Track, August 14-22, 1969

The latter was within the established operational limits.

Satellite information was used by National Hurricane Center as an alternative means of tracking the storm. It was particularly valuable in tracking CAMILLE in its incipient stages across the tropical North Atlantic from Africa. It was a valuable tool in directing the aerial reconnaissance flights into the right areas and provided good estimates of CAMILLE's position at times of doubtful aerial fixes.

ATS–III pictures are acquired by NASA at Rosman, North Carolina. Pictures from this satellite were taken during the period of August 15 through 21, from approximately 4:30 am EST through 6 pm EST. Pictures were taken each day at 10-minute intervals. No communications were available to transmit these pictures to NESC or Miami for interpretation. If these data had been available, they would have been useful in estimating the rate of growth of the storm as well as estimates of the environmental winds over the ocean and seas.

It is recommended that data from the existing Applications Technology Satellite series be made available to the hurricane warning service on a real-time basis until the Geostationary Operational Environmental Satellite system enters service.

E. Aerial Reconnaissance*

In the National Hurricane Operations Plan the policy is established that "The Air Force and Navy will share the reconnaissance responsibility on an equal basis for providing fixes and investigative flights on tropical cyclones and hurricanes in the Atlantic, Caribbean and Gulf of Mexico areas in accordance with the following; . . ." The Director of the National Hurricane Center has the responsibility for

identifying the operational requirements for hurricane reconnaissance. He is charged with the responsibility of advising the Chief, Aerial Reconnaissance Coordinator, Atlantic Hurricanes, (CARCAH) of the aircraft reconnaissance requirements of the hurricane center. The CARCAH is responsible for the coordination and the final preparation of the reconnaissance Plan of the Day and for the scheduling of aircraft required to meet the provisions of the plan. Furthermore, the National Hurricane Operation Plan stipulates that plans for aircraft reconnaissance shall be prepared by the CARCAH in consultation with the Director of the National Hurricane Center. When the flights by ESSA Research Flight Facility are to be made, the Chief of the Research Flight Facility will participate in the planning. In practice and in accord with the agreement between the Air Force and Navy to share the responsibility for hurricane reconnaissance, the Research Flight Facility participates only in hurricane reconnaissance whenever it is necessary in and over the territory of Cuba. This is because the Cuban Government has given permission for only civilian aircraft of the United States to fly over Cuba in connection with hurricane reconnaissance. The plan proceeds to identify that requirements for operational data are primary and suggests that every possible effort should be made to meet the requirements for research data, implying that this should be done without affecting the fulfillment of the needs for operational data.

A review of the aerial reconnaissance activity based upon the records retained by CARCAH, reveals the following chronology:

1. CAMILLE was located by Navy reconnaissance at 1440 GMT on August 14, 1969, at 19:05N and 81.45W. Lowest sea-level pressure was 999 mb with a maximum surface wind of 50 knots. At 0045 GMT on August 15, Navy reconnaissance fixed the position at 19:57N and 81:10W. The lowest sea-level pressure was recorded as 991 mb with maximum surface wind of 50 knots. At 0600 GMT reconnaissance placed the position of the hurricane at 20:02N and 83:19W. A subsequent analysis of these positions based upon a comparison with the "best track" of the hurricane derived from all information available, including satellite, radar, and surface weather reports, indicates that the 0045 GMT position on the 15th was off the "best track" by approximately 40 miles.

2. While the hurricane was immediately south of Cuba, the ESSA Research Flight Facility performed the reconnaissance because of the restriction upon military overflight of Cuba.

3. On August 16 the Air Force aborted its mission at 0000 GMT due to the loss of radar and radio.

4. The Navy accomplished four radar fixes on the center of the storm at 0500, 0640, 0900, and 1200 GMT on the 16th. On the later fix the lowest sea-level pressure of the storm was reported to be 996 mb with a surface wind of 80 knots.

5. An Air Force penetration of the storm was accomplished at 1835 GMT on the 16th at 24:22N and 86:04W when, at this time, a central sea-level pressure of 908 mb was reported, which was a new record for lowest pressure of any Atlantic hurricane. Six hours later at 0016 GMT August 17 the same Air Force crew reentered the storm at 25:15N and 87:14W and reported surface wind of 90 knots and a central pressure of 905 mb.

6. On August 17 the Navy again provided five fixes by radar. Penetration was not attempted because of the storm's intensity. An analysis of the reported positions and their comparison with the "best track" position indicate there may have been some navigational difficulties or radar positioning problems experienced inasmuch as the first and second positions of this group deviate significantly from the "best track." However, the other fixes were on "best track."

7. Finally, the Air Force penetrated the storm at 1815 GMT on the 17th at 28:12N and 88:46W, established the central sea-level pressure at 901 mb and the surface wind at 180 knots. A truly great hurricane. At this time the hurricane was under the surveillance of several shore-based radars and no further aerial reconnaissance was requested.

This chronology is shown in Figure 5.

The National Hurricane Center has established requirements for the reconnaissance aircraft to establish the position of the hurricane, the lowest sea-level pressure in the storm, and the maximum surface winds. These are specified in the National Hurricane Operations Plan.

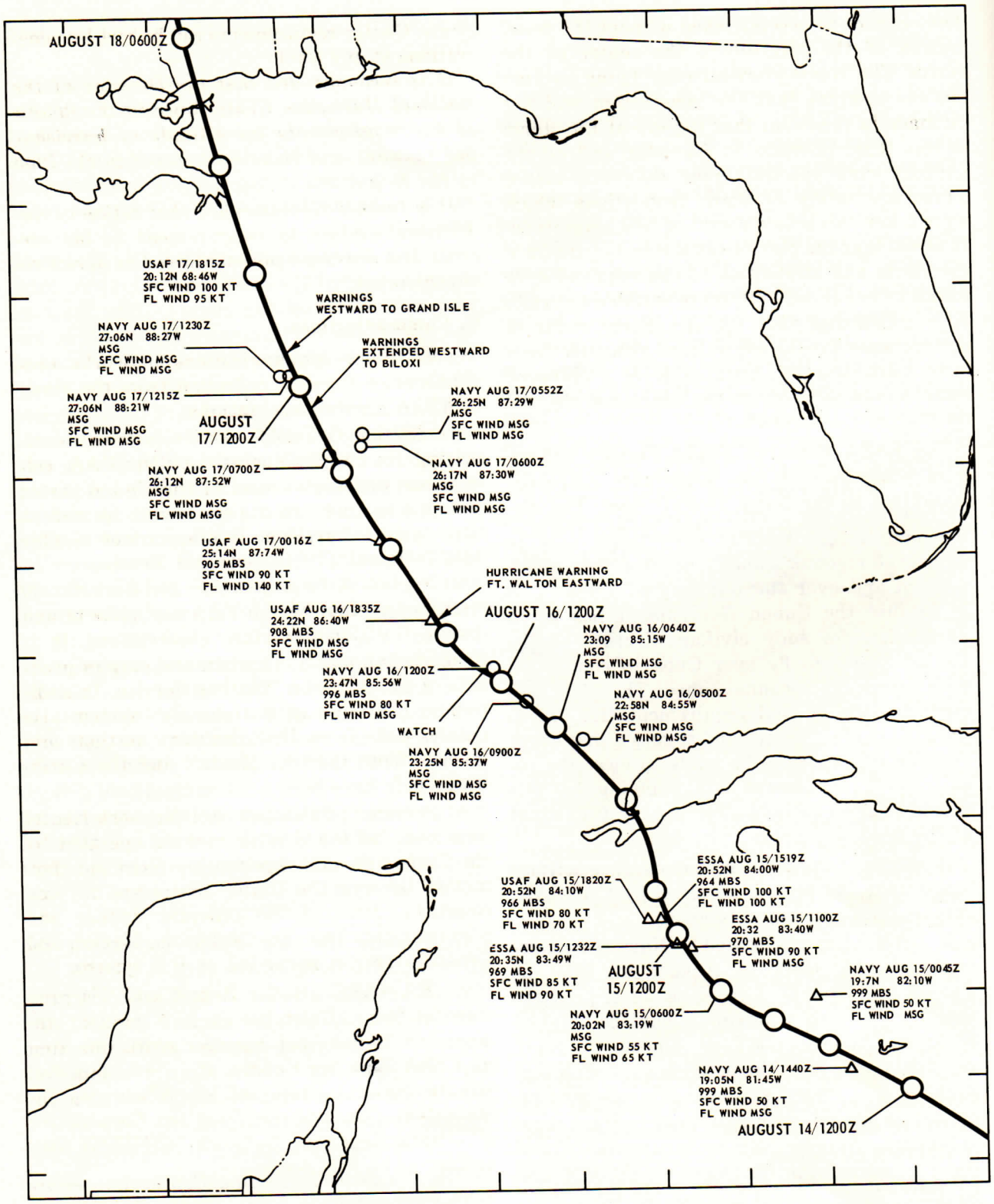


Fig. 5.—Summary of Aircraft Reconnaissance

They cannot be accomplished without the penetration of the aircraft to the center of the storm. The Navy procedure for flying in hurricanes specifies that the penetration will not be made in the event that the eye of the storm is less than 15 miles in diameter and/or the surface wind speeds higher than 120 knots. These are safety of flight restrictions which were a key factor in a storm of this magnitude. It seems that the Navy's capability to penetrate the storm and acquisition of the required data would be enhanced with more suitable aircraft. It is established that the Air Force radar is not optimum for the job at hand although there is no assurance that installation of a different radar would not change the operating characteristics of the aircraft.

The ESSA Research Flight Facility suffers from a number of the deficiencies currently recognized in the Navy aircraft fleet. The observational equipment package aboard the Research Flight Facility is outdated. The aircraft platforms are roughly of the same vintage as those operated by the Navy and are overdue for replacement by modern aircraft. The Research Flight Facility is not, however, operationally restricted to flying into hurricanes. Because of aircraft and equipment limitations currently experienced by the Air Force and the Navy, the operational mission of the Research Flight Facility should continue to provide support to the hurricane reconnaissance program. This should cover at least the period of time required to modernize the Department of Defense equipment currently in use. It would permit a larger choice of equipment at times when penetration might not otherwise be possible.

A standardized instrument package for the use of both the operational and R&D type reconnaissance should be developed. This would require considerable coordination among the three services both in the coordination and the development of requirements. It would enhance the use of data for research purposes collected by different aircraft.

Finally, it is noted that the Navy reconnaissance operations are conducted at 1500 feet or less above sea level. This stems from a Navy requirement for data and it is noted that penetrations at this level are not a requirement of the National Hurricane Center. National Hurricane Center requirements can be met by penetrations at any level.

It is recommended that the Director of the National Hurricane Center specify the details of his requirements for altitude of hurricane penetrations, and these be included in the Plan of the Day.

*It is further recommended that action be undertaken leading to improvement in the aircraft and sensory equipment used in aerial reconnaissance.**

F. Communications

Five major communications networks provide service for data collection from the array of ESSA observation stations:

a) Service C Teletypewriter Network comprising six circuits operated by the FAA, collects and distributes most of the United States synoptic surface and upper-air data as well as basic public forecasts. It also carries similar data from parts of Canada and Mexico.

b) Service A Teletypewriter Network has 60 circuits operated by the FAA and collects and distributes hourly surface observations. It is primarily an aviation system and carries products of the Aviation Weather Service. In addition to U.S. civilian stations, this system also carries data from U. S. military stations and reports from Canada, Mexico, and the Caribbean.

c) Service O Teletypewriter Network has 23 long line, radio and cable circuits operated by the FAA, and exchanges meteorological information between the United States and foreign countries. Most of the synoptic surface and upper-air data from the Caribbean, Mexico, and Central America is carried on this system.

d) RAWARC (Radar Report and Warning Coordination) Teletypewriter Network employs five 75-word-per-minute circuits operated by ESSA Weather Bureau. It collects and distributes radar reports and storm warning information. Observations from the Cooperative Hurricane Reporting Network (CHURN) may be carried on this system.

e) East Coast Circuit (7072), operated by

*A special analysis of hurricane reconnaissance needs is being undertaken by the Federal Coordinator for Meteorological Services and separate recommendations on this phase of the hurricane tracking problem will be made.

ESSA Weather Bureau, collects and distributes surface and upper-air data from land stations and ships operating in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico. It also carries forecasts and adminstrative traffic.

No unusual problems were reported in the collection of observational data essential to the preparation of forecasts and warnings applicable to hurricane CAMILLE. It should be noted, however, that as a consequence of automation of the Aeronautical Fixed Telecommunications Net (AFTN) there has been a big turnover in FAA communications personnel at Miami and San Juan.

Operating with staff vacancies and inexperienced personnel contributes to the delay and sometimes loss of surface and upper-air observations and aircraft reconnaissance reports needed to support hurricane forecasting.

Considerable difficulty has been experienced in communicating to National Hurricane Center significant reconnaissance information concerning the position and intensities of hurricanes. The utilization of high-frequency radio communications facilities, in-flight, frequently requires time-consuming relays because of propagation difficulties. The utilization of a synchronous satellite for communications relay might be a solution.

It is recommended that the Department of Transportation's Federal Aviation Administration be apprised of the impact of any loss or delay of information used in issuing hurricane warnings.

It is further recommended that a comparative study be made of existing high-frequency radio, satellite microwave, and other communications systems, to determine the best system for use in hurricane emergencies.

At the National Hurricane Center in Miami, a meteorologist studies mosaiced satellite photographs of hurricane. (From motion picture HURRICANE!)

Chapter IV

The Forecasts of CAMILLE

It is clear that the warning was timely as evidenced by the massive evacuation that was completed before the storm struck. A review of Attachment A which details the chronology of the forecasts, warnings, and advisories concerning CAMILLE shows that a consistent bias existed in the early prediction of CAMILLE's motions. These early forecasts consistently indicated a more easterly movement than was actually experienced. However, this was adjusted at 5 am August 17 to provide 15 hours of warning to the particular segment of the coastline most affected. More time would have been desirable. However, the team agrees that the forecasts issued compare favorably with the capability of the state of the meteorological science and our present understanding of hurricanes.

The National Hurricane Center has developed and uses special meteorological tools including climatological probability data designed for the specific job of forecasting hurricanes. The forecaster varies his tools for the job to be done. At this time there is no substitute for experience, since much of the decision process is based upon subjective evaluation of the relative significance of the several meteorological variables.

It is standard practice to evaluate all official forecasts of hurricane motion with the best estimate of the track of the storm. Table II provides the "best track" of hurricane CAMILLE at the times indicated. Here the positions predicted by the official forecast are also compared with the positions predicted by the best objective statistical forecast. This statistical forecast is referred to as NHC-67 and it is designed for use with 00 GMT and 12 GMT input data only. When comparing the official forecast with either the "best track" or the objective forecast, one must remember that the error in forecast position is made up of two parts: the first is the error of the initial position; the second is the prediction error. These two errors define a vector which represents the displacement error in anticipating the future position of the storm. In the case of the first error, the present ability to position the storm by the best method (aerial reconnaissance) is probably no better than about ± 10 miles. Satellite reconnaissance can position the storm with an accuracy of about ± 18 miles. The error in predicted displacement is a function of the forecasters' skill and meteorological knowledge. It will vary from the one meteorological situation to another largely because of an imperfect understanding and description of the atmospheric process involved. Bearing this in mind the average error in the official forecasts, computed from the "best track" position, is approximately 100 miles in 24 hours. This compares with the long-term average error experienced in the eastern Gulf of Mexico of 115 miles in 24 hours. The average error in predictions using the NHC-67 objective forecast was not significantly different. A comparison of these forecasts is shown on Figures 6 and 7.

The ESSA Weather Bureau has assigned to its National Meteorological Center the responsibility for the preparation of broad-scale forecasts to be used as guidance by its forecast offices. The individual forecast offices adapt this material to the particular forecast problem at hand. The National Hurricane Center is a prime user of these materials as basic input to hurricane predictions. The following illustrates how they can be used.

One of the problems faced by the hurricane forecaster Saturday evening, August 16, was the influence on CAMILLE of a 500-millibar trough then over the Mississippi Valley. A significant eastward movement of this trough would favor a recurvature of CAMILLE while, if the trough remained stationary or moved very slowly, continued north-northwest movement of CAMILLE could be expected. Here the National Hurricane Center is dependent upon the National Meteorological Center for the prediction of such large-scale mid-latitude fea-

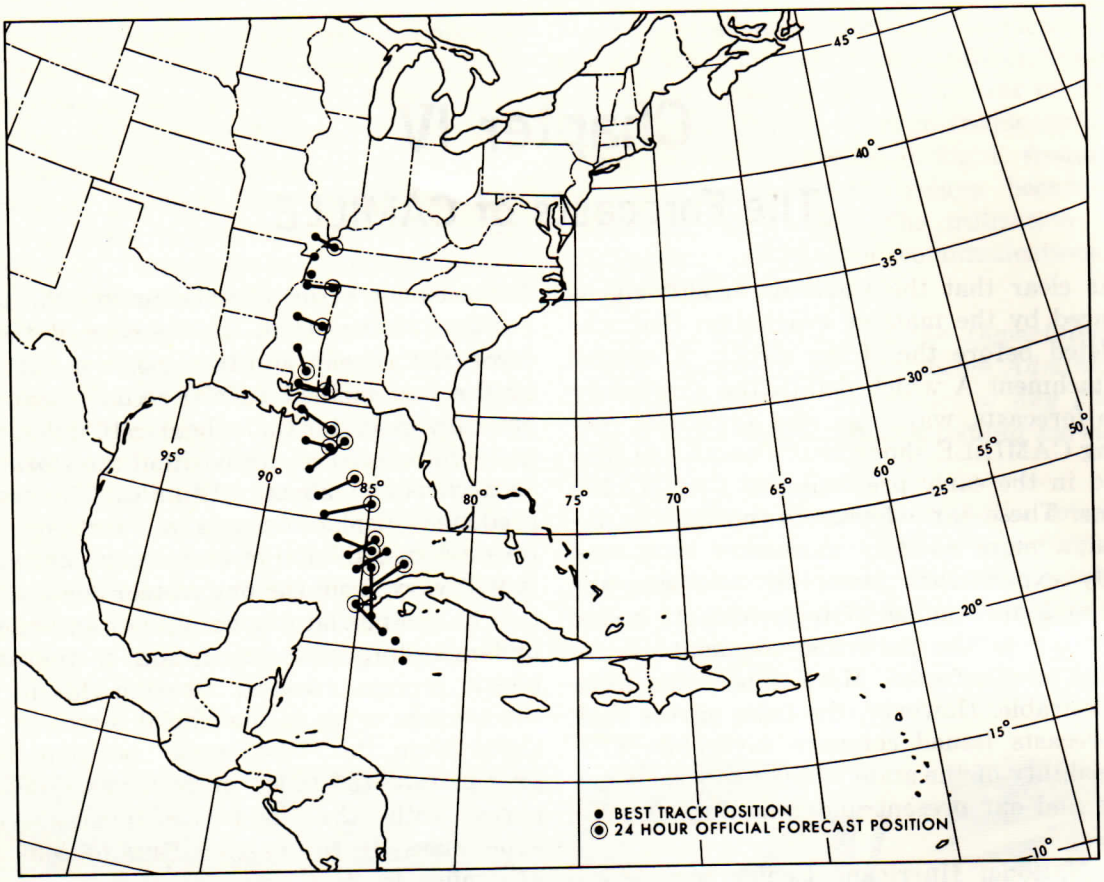


Fig. 6.—Official Forecast Displacement Error

Table II

"BEST TRACK" POSITIONS OF HURRICANE CAMILLE

		Best Track Position		Advisory Position		24 hr. Official Forecast Position verifying Date/time.		24 hr. NHC 67 Forecast Position verifying Date/time.	
Date	Time	Lat.	Long.	Lat.	Long.	Lat.	Long.	Lat.	Long.
8/15	00Z	19.7	82.7	20.0	82.0				
	06Z	20.3	83.3	20.5	83.0				
	12Z	20.7	83.8	20.6	83.8	22.0	85.0		
	18Z	21.2	84.1	21.1	84.1	23.2	84.6		
8/16	00Z	22.3	84.4	21.9	84.5	23.5	83.0	23.0	83.5
	06Z	23.1	85.2	23.2	85.0	24.0	84.0		
	12Z	23.7	85.9	24.0	85.7	24.3	84.6	23.4	85.2
	18Z	24.2	86.5	24.7	86.1	24.0	84.8		
8/17	00Z	25.2	87.2	25.2	87.2	26.0	85.0	25.1	85.4
	06Z	26.0	87.7	26.4	87.5	27.0	86.0		
	12Z	27.0	88.2	27.2	88.1	28.5	87.2	28.8	86.0
	18Z	28.3	88.7	28.2	88.8	28.2	87.2		
8/18	00Z	29.4	89.1	29.5	89.1	28.9	87.2	28.8	87.2
	06Z	30.7	89.6	30.5	89.6	30.5	88.0		
	12Z	32.2	90.0	32.3	90.0	31.2	89.1	31.5	87.6
	18Z	33.4	90.1	33.5	90.1	33.0	88.5		
8/19	00Z	34.7	90.0			35.0	90.0	32.9	89.6
	06Z	36.0	89.3			35.0	90.0		
	12Z	37.0	88.0			37.4	90.5		

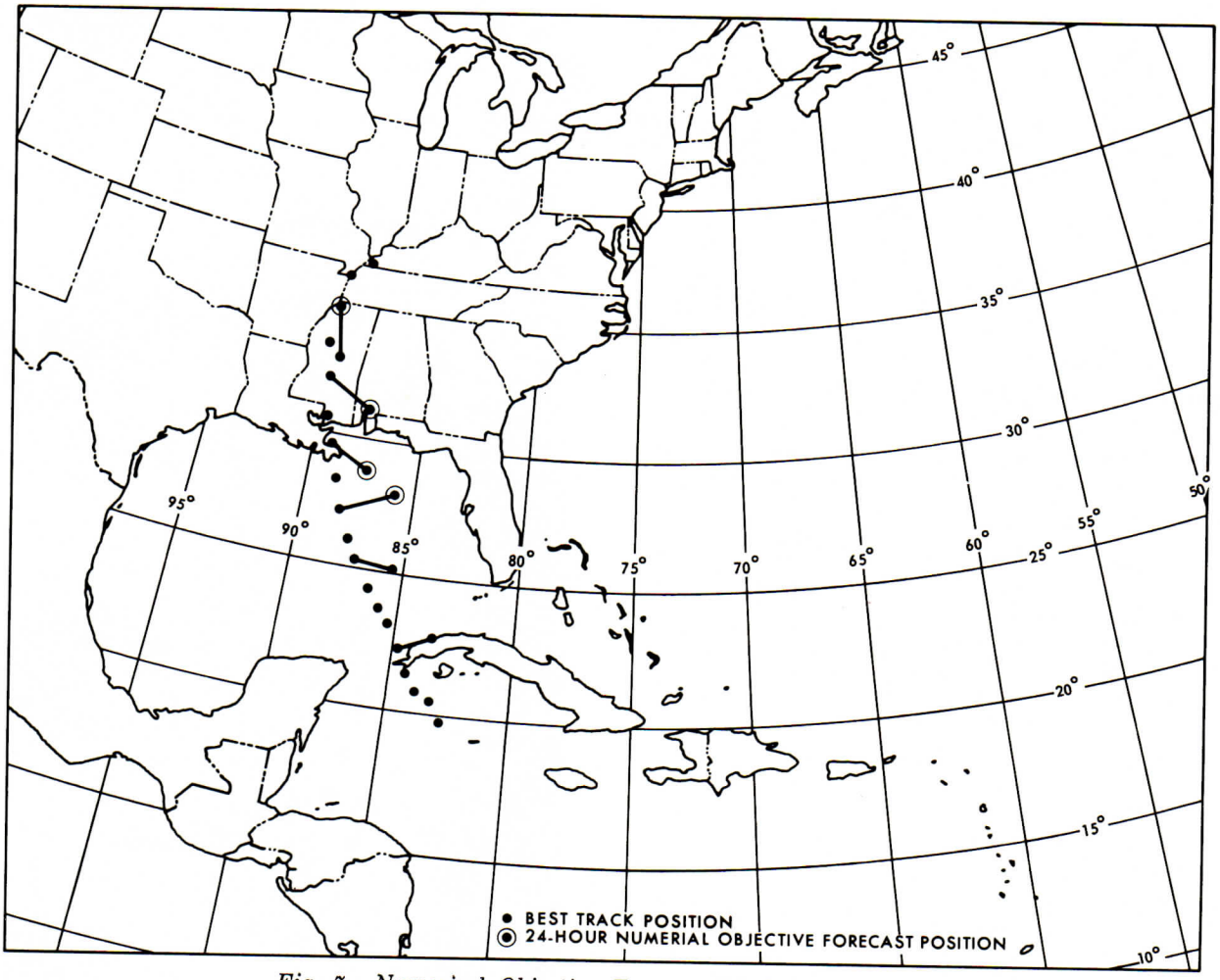


Fig. 7.—Numerical Objective Forecast Displacement Error

tures. Figure 8 shows the 24-hour 500-millibar forecast prepared at the National Meteorological Center. It successfully predicted the behavior of the important features over the southeastern United States. This guidance forecast is typical of such forecasts provided during the period.

An important operational objective of the warning service is to improve the diagnostic techniques for the tropical regions. Advances in technique development have not been as rapid as in the more northern latitudes and the team concurs that improvement is desirable. The utilization of low-level winds derived from emerging satellite technologies offers considerable promise.

Increasing dependence is being placed upon improved atmospheric prediction models. The largest single deterrent to use of improved models is necessarily related to the input data. Thus a solution or circumvention of this obstacle is vital. Fortunately, technology in the form of the Geostationary Environmental Satellite and ATS-III satellites will permit a breakthrough here by improving the observational system supporting forecast operations. Details on tropical wind circulations that are not otherwise available and vital to successful predictions will become available within about three years.

Finally, the team believes that the performance of existing prediction models indicates that there is considerable potential for improving the accuracy of the prediction of hurricane motion through the development of improved mathematical models. A reduction in the prediction error from the present average of 115 miles in 24 hours to the order of 75 miles seems possible.

It is recommended that a major research and development program be mounted with

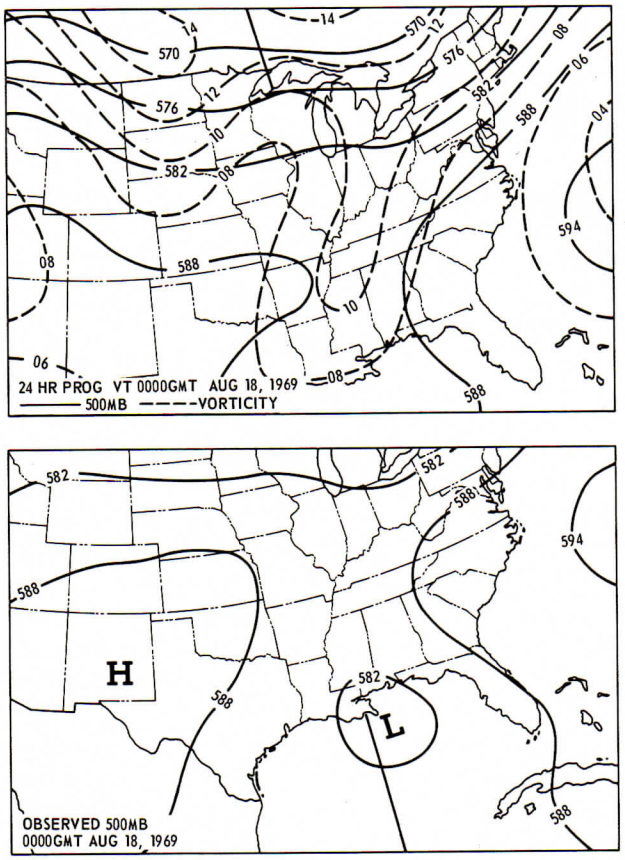
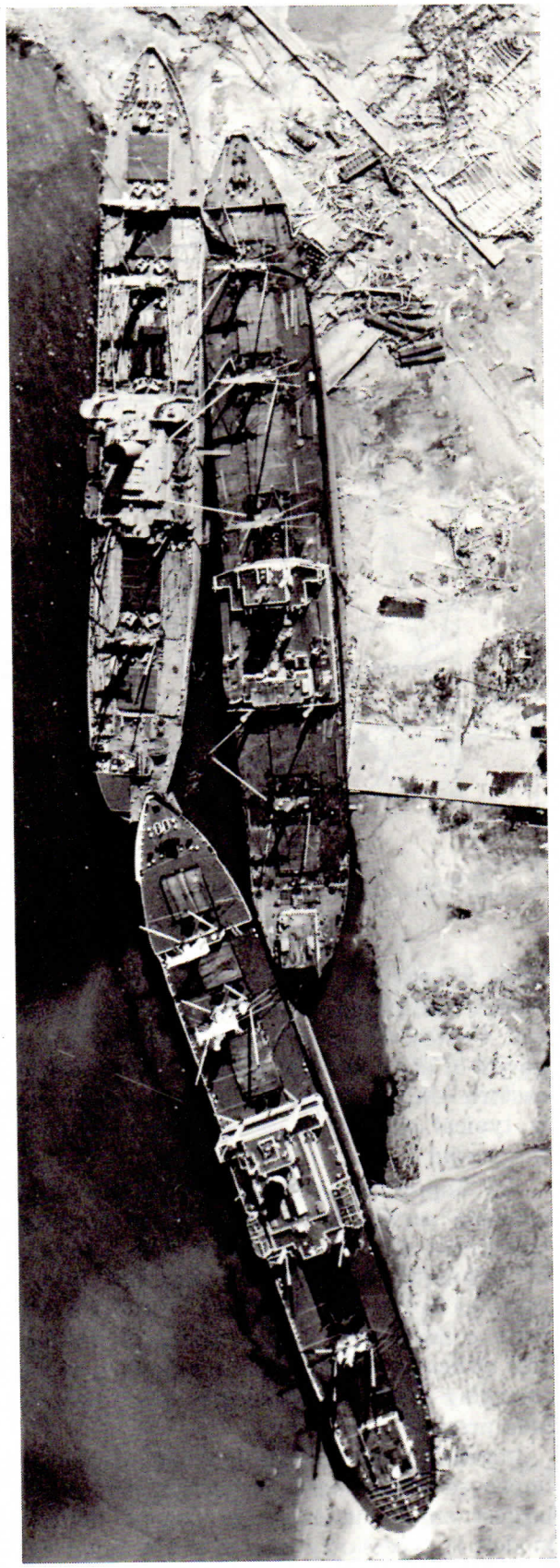


Fig. 8.—NMC Forecast and Verification, 0000Z August 18, 1969

principal attention given to improvements in operational hurricane forecasting. Such an effort should include the development of improved tropical analysis technique using low level winds derived from synchronous satellite data and the development of better numerical prediction models. It is further recommended that ESSA set a goal of reducing the displacement error (between predicted and observed position) to the order of 75 miles in 24 hours by 1974.



Ocean-going ships beached by CAMILLE at Gulfport, Mississippi.

Chapter V

Economic Aspects and Priorities

CAMILLE had the potential of becoming the greatest national disaster in the history of the United States. It is estimated that the 15-hour warning given the people between New Orleans and the Florida panhandle on August 17 saved 50,000 lives. Without putting a price on human life, it is evident that the hurricane warning service and community actions which keep the the population prepared for such disasters are earning their way. Here the success was not the result of an ability to predict with precision for long periods in advance the course of the storm. Rather, it was the utilization of the warning in conjunction with an extensive preparedness action leading to a planned response to a specific warning.

Because of the size of their investments, large shipping and industrial activities can be expected to be responsive to hurricane warnings. This is not the case with the general public. It has been estimated* that normally we may only expect that 20 percent of the population will take protective action in response to hurricane warnings. If this estimate is accepted, then it follows that increased use of existing services through the placing of more emphasis on public education and community preparedness programs will pay large dividends. Within the overall hurricane warning service system including the data acquisition, communications, processing, interpretation, dissemination, information, and preparedness subsystems, we are convinced that additional incremental expenditures in public education and community preparedness programs will provide the largest immediate benefits. This will be true until the majority of the communities along the U. S. Gulf and Atlantic coastline are prepared to respond as was the case in CAMILLE. We do not believe that such response is uniformly possible now.

*Arnold A. Sugg, "Economic Aspects of Hurricanes," *Monthly Weather Review*, Vol. 95, No. 3, March 1967, pp. 143–146.

Of nearly equal importance to public education and preparedness is the continuing production of quality service by Weather Bureau facilities during storms. The need for maintaining an "official voice" from the Weather Bureau seems paramount in disasters such as this.

While much has been learned about hurricanes, skill in their forecasting has reached a plateau. The principal obstacles are related to the improvements of the acquisition of meteorological data and development of improved atmospheric models whose rapid numerical solution will result in better forecasts. The survey team feels that improved forecast techniques can reduce the 24-hour prediction error from the present 115 miles in 24 hours to the order of 75 miles. If accomplished this would reduce significantly the unnecessary costs resulting from overwarning. In that regard Sugg's study* suggests protective action reduces losses by 50 percent; from this an estimate is made that the hurricane warning service saves in excess of $32 million while spending or causing to be spent an additional $7 million during the average season. Gross forecast errors could cause unnecessary costs which might range up to $17 million.

The strengthening of the hurricane warning system requires all three actions indicated above. The establishment of priorities is fundamental to their orderly accomplishment. *It is recommended that highest priority be given to the following:*

1. *Public education and community preparedness programs.*
2. *Improved aircraft reconnaissance.*
3. *Safe quarters and reliable power and communication facilities.*
4. *Forecasting research and technique development based upon new technologies, to be accelerated as we approach a minimum standard of preparedness and public awareness of the consequences of a failure to respond to hurricane warnings.*

Attachment A

Summary of CAMILLE's Forecasts and Warnings

On Thursday, Aug. 14, a Navy reconnaissance plane reconnoitering a tropical wave in the Caribbean encountered a fast-developing depression which reached storm intensity while the aircraft was still in the area. Advisory Number One on the new storm, to be known as Camille, was issued at 1 p.m. EDT that day by the Weather Bureau's National Hurricane Center in Miami.

At that time, Camille was located near latitude 19.3 north and longitude 82.3 west or about 60 miles west of Grand Cayman or 408 miles south of Miami. Camille was moving west-northwestward at about 13 miles per hour with strongest winds about 60 miles per hour over a very small area near the center. A bulletin was issued at 3 p.m. Advisory Number Two was issued at 6 p.m. on Aug. 14, saying indications were that the storm would pass near the western tip of Cuba that night or early the next morning, moving northwestward at 10-12 miles per hour. It was forecast that the storm would go into the Gulf of Mexico.

Another bulletin was issued at 9 p.m. EDT on the 14th, indicating no important change.

At midnight Thursday, Aug. 14, Advisory Number Three was issued. It stated that Camille took a more northerly course. This was based on a Navy reconnaissance flight report. At that time, there was no significant change in intensity.

A bulletin was issued on Friday, Aug. 15 at 3 a.m. stating that Camille was "plodding" toward the Isle of Pines. At 6 a.m., on Friday, Aug. 15, Advisory Number Four was issued, stating that Camille was still heading toward extreme western Cuba with indications that hurricane force would be reached that morning and hit extreme western Cuba around noon or a little later. It forecast a slight turn to more northerly movement after Camille passed Cuba and would enter the Gulf of Mexico later that day. At 9 a.m. that day, a bulletin said Camille had become a full-fledged hurricane. An ESSA reconnaissance plane found Camille had highest winds estimated at 90 miles per hour. Advisory Number Five, issued at noon Friday, Aug. 15, indicated that hurricane Camille was centered near latitude 21.2 north, longitude 83.9 west, or about 400 miles southwest of Miami. It stated that Camille would reach western Cuba around noon or a little later and precautions should be taken immediately for rapidly increasing winds reaching hurricane force by early afternoon and tides up to eight feet on Cuba's southwest coast.

It forecast a turn to a more northerly course, and an increase in forward speed which would bring the storm into the Gulf of Mexico by evening. It pointed out that small craft around the Florida keys should not venture far from shore and those around Western Cuba should be in safe harbor. A bulletin issued at 3 p.m. on Friday, Aug. 15, said that an ESSA reconnaissance plane reported steady intensification, and somewhat slower movement as it approached southwest Cuba coast. The eye of the hurricane was clearly in view of the weather radar in Havana, which was supplying regular reports to the National Hurricane Center. This bulletin said Camille, while still an immature young hurricane with a very small intense core, was nevertheless the most intense hurricane since Beulah of 1967. Maximum winds were at least 115 miles per hour and over water areas gale force winds extended outward into the eastern Florida strait area. At 6 p.m. on Friday, Aug. 15, Advisory Number Six was issued, stating that the storm was at latitude 21.5 north and longitude 84.4 west or about 270 miles southwest of Key West. This position was based upon Air Force reconnaissance, land-based radar, ship, and island reports. It said the hurricane was expected to enter the Gulf of Mexico early Saturday morning, Aug. 16 and proceed north over the eastern Gulf at a slightly increased forward speed. It stressed that all interests along the eastern Gulf of

Mexico should remain in close touch with all future advisories and bulletins. A bulletin was issued at 9 p.m. Friday, Aug. 15, stating the eye was over extreme western Cuba and was under surveillance of the Key West and Havana radars. Another bulletin, citing no change, was issued at 11 p.m.

At midnight Friday, Aug. 15, Advisory Number Seven was issued. It stated that small craft around Florida should observe caution. It called Camille "a dangerous hurricane" entering the east portion of the Gulf of Mexico and said it "poses a great threat to the United States mainland." It urged all interests along the eastern Gulf of Mexico to keep in close touch with advisories. It stated that a hurricane watch probably would be issued for a portion of the coastal area of the northeast Gulf by or before noon Saturday, Aug. 16.

A bulletin issued at 3 a.m. Saturday Aug. 16 located Camille near latitude 23.2 north and longitude 85.0 west or about 220 miles west-southwest of Key West, moving north-northwest at ten miles per hour, with winds estimated at 100 miles per hour near the center. At 6 a.m. Saturday, Aug. 16, Advisory Number Eight said the hurricane threatened northwest Florida. It said that small craft along the northwest Florida coast and as far west as Mobile, Alabama, should seek safe harbor that night. It added that a hurricane watch "undoubtedly" would be needed over most of that area later that morning, and warnings for a portion of the area that afternoon.

Advisory Number Nine, issued at 9 a.m. Saturday, Aug. 16, said "a hurricane watch is in effect from Biloxi, Mississippi, to St. Marks, Florida, at 8 a.m. CDT. Specific hurricane warnings will be issued for portions of this coastline at noon today following receipt of further reconnaissance information from the center of hurricane Camille." It stated that the strongest winds were expected to remain not less than 100 miles per hour, with further intensification expected. It said Camille was "potentially a very dangerous hurricane. All interests in the watch area and adjacent coastlines should remain in close touch with later advices today and be prepared for fast protective action when warnings are issued."

At 11 a.m. CDT on Saturday, Aug. 16, Advisory Number Ten was issued from the New Orleans Weather Bureau office. It stated that hurricane warnings had been issued on the northwest Florida coast from Fort Walton to St. Marks and gale warnings elsewhere from Pensacola to Cedar Key, effective at 11 a.m. that day, CDT. It added that "preparations for hurricane force winds and five-to-ten-foot tides in the area from Fort Walton to St. Marks should be started immediately and completed tonight." At 11 a.m., she was centered near latitude 24.5 and longitude 86.0, or about 380 miles south of Panama City, Florida, moving north-northwestward about 10 miles per hour. It added the hurricane was expected to continue that movement that day, with a gradual turn to the north that night. A slight increase in speed was said to be likely that night and the following day. Highest winds were estimated at 115 miles per hour near the center, with gales extending out about 150 miles from the center. Conditions were said to be favorable for further increase in intensity that day. A bulletin was issued that day at 1 p.m., repeating the information. Another bulletin was issued at 3 p.m., stating Camille had stalled temporarily, but was expected to resume its north-northwestward movement at about 10 miles per hour that night. At 5 p.m. CDT the bulletin said the hurricane had become very intense and repeated safety precautionary information, along with the area watch and warning.

A 7 p.m. CDT bulletin repeated the information and called Camille "a very intense and dangerous storm." At 9 p.m. CDT on Saturday, Aug. 16, Advisory Number Eleven was issued. It gave the location as latitude 25.4 north and longitude 87.3 west, or about 350 miles south of Pensacola, Florida, moving north-northwestward about twelve miles per hour, with highest winds estimated at 150 miles per hour near the center. At 11 p.m. CDT that night, Advisory Number Twelve was issued, stating that Camille was "extremely dangerous," repeating the watch and warning area and predicting little intensity change over the next twelve hours. A bulletin at 1 a.m. CDT Sunday, Aug. 17, continued to call the storm extremely dangerous, and repeated the watch and warning areas. A 3 a.m. bulletin said that the hurricane was located by a Navy reconnaissance plane near latitude 26.7 north and longitude 86.7

west or about 260 miles south of Pensacola, Florida, moving on a course a little west of north at about twelve miles per hour. A slight change to a more northerly course was said to be indicated with little change in forward speed. The plane found Camille still well organized, with a small compact eye. Highest winds were estimated at 160 miles per hour near the center.

At 5 a.m. CDT Sunday, Aug 17, Advisory Number Thirteen was issued. It called Camille "extremely dangerous" and said that she had shifted a little westward, threatening Mississippi, Alabama, and the northwest Florida coast. Hurricane warnings were extended westward to Biloxi, including the Alabama coast and the Pensacola area of northwest Florida. Hurricane watch and gale warnings were extended westward to New Orleans and Grand Isle, Louisiana.

It said: "Hurricane warnings are now in effect from Biloxi, Mississippi, to St. Marks, Florida, and gale warnings elsewhere from New Orleans and Grand Isle to Cedar Keys, Florida." It said preparations should be completed as early as possible that day in the area of hurricane warnings and persons in the area of hurricane watch should be prepared to take quick action if necessary. It called for winds to increase and tides to start to rise along the northern Gulf coast from Grand Isle eastward. It forecast tides up to 15 feet in the area where the center was to cross the coast and up to five to twelve feet elsewhere in the hurricane warning area. "Evacuation of the low-lying area that would be affected by these tides should be done as early as possible today before escape routes are closed. The center is expected to move inland near Mobile tonight." A bulletin issued at 7 a.m. CDT Sunday, Aug. 17, stated that the movement of hurricane Camille during the past few hours had been generally toward the mouth of the Mississippi River and "unless the anticipated turn to a more northerly course occurs within the next few hours, it will be necessary to extend hurricane warnings into the area of hurricane watch."

Advisory Number Fourteen issued at 9 a.m. CDT on Sunday, Aug. 17, extended warnings westward to include all of the Mississippi coast and southeastern Louisiana as far west as New Orleans and Grand Isle.

It stated: "Gale warnings have been extended westward to Morgan City, Louisiana. Hurricane warnings are now in effect from New Orleans and Grand Isle, Louisiana, eastward across the Mississippi, Alabama, and northwest Florida coasts to St. Marks. Gale warnings are now in effect elsewhere from Morgan City to Cedar Keys, Florida. Preparations against this extremely dangerous hurricane should be completed within the next few hours.

"Winds are increasing and tides are rising along the northern Gulf coast from Grand Isle eastward. Gales have begun a short distance offshore and will be spreading inland over the warning area today and will reach hurricane force from southeast Louisiana across coastal Mississippi, Alabama, and extreme northwest Florida by late this afternoon or early tonight. Tides up to 15 feet are expected in the area where the center crosses the coast and tides of five to 12 feet elsewhere in the hurricane warning area. Evacuation of the lowlying area that will be affected by these tides should be done as early as possible today before escape routes are closed. Present indications are that the center of Camille will pass close to the mouth of the Mississippi River late this afternoon and move inland on the Mississippi coast tonight." At 9 a.m., the hurricane was located near latitude 27.4 north and longitude 88.4 west or about 200 miles southeast of New Orleans, moving north-northwest at about twelve miles per hour. Highest winds were estimated at about 160 miles per hour near the center. Hurricane force winds extended outward 50 miles, gales 150 miles from the center. Camille then was under the surveillance of radars at New Orleans, Pensacola, and Apalachicola.

A bulletin issued at 1 p.m. CDT on Sunday, Aug. 17, repeated the fact that Camille was extremely dangerous and moving toward the mouth of the Mississippi River, repeated the areas of watch and warning, and stated that "several tornadoes are likely over extreme southeast Louisiana eastward to Fort Walton, Florida, and up to 100 miles inland this afternoon and tonight." Advisory Number Sixteen, issued at 3 p.m. CDT Sunday, Aug. 17, discontinued warnings east of Apalachicola and continued warnings at New Orleans and Grand

Isle, Louisiana, eastward across the Mississippi, Alabama, and northwest Florida coasts to Apalachicola. It pointed out that winds were increasing and tides rising along the northern Gulf coast from Grand Isle eastward. It urged immediate evacuation of areas affected by tides, and repeated the other warnings. An Air Force reconnaissance flight into Camille Sunday afternoon, the advisory stated, estimated the winds at 190 miles per hour near the center with hurricane force winds extending outward 60 miles and gales outward 180 miles from the center.

On Sunday, Aug. 17 at 5 p.m. CDT, Advisory Number Seventeen was issued. It stated:

"Hurricane warnings are in effect from New Orleans and Grand Isle, Louisiana, eastward across the Mississippi, Alabama, and northwest Florida coast to Apalachicola. Gale warnings are in effect from Morgan City to Grand Isle. Preparations against this extremely dangerous hurricane should be completed before dark.

"Winds are increasing and tides are rising along the northern Gulf coast from Grand Isle eastward. Hurricane force winds are now occurring at the mouth of the Mississippi River. Gales in squalls are spreading inland over the warning area and winds will reach hurricane force over much of the area from southeast Louisiana across coastal Mississippi, Alabama, and into extreme northwest Florida later this afternoon or by early tonight. The following tides are expected tonight as Camille moves inland: Mississippi coast, Gulfport to Pascagoula, 15 to 20 feet. Pascagoula to Mobile, 10 to 15 feet. East of Mobile to Pensacola, six to 10 feet. Elsewhere in the area of hurricane warning east of the Mississippi River, five to eight feet. Immediate evacuation of areas that will be affected by these tides is advised.

"The center of Camille is expected to move inland on the Mississippi coast near Gulfport early tonight. Several tornadoes are likely over extreme southeast Louisiana eastward to Fort Walton, Florida, and up to 100 miles inland through tonight. Any flood statements needed will be issued by the local Weather Bureau offices. . ."

A bulletin issued at 7 p.m. CDT on Sunday, Aug. 17, added that heavy rains with local amounts eight to ten inches would spread into southeast Mississippi, southwest Alabama, and the Florida panhandle that night. At that time, the center of hurricane Camille was located by New Orleans and other landbased radar near latitude 29.5 north, longitude 89.1 west, or about 70 miles east-southeast of New Orleans and 60 miles south of Gulfport, Mississippi, moving north-northwest about 15 miles per hour. Highest winds were estimated at 190 miles per hour with hurricane force winds extending outward 60 miles and gales 180 miles from the center.

Advisory Number 18 was issued at 11 p.m. CDT on Sunday, Aug. 17. It reported Camille moving inland near Gulfport, Mississippi. It repeated the hurricane warnings and urged precautions be continued. It stated that hurricane force winds were then occurring over most of the warning area. It again forecast heavy rains and the tides quoted earlier.

It said that "those in the path of the eye are reminded that the winds will die down suddenly if the eye passes over your area but the winds will increase again rapidly and from the opposite direction as the eye moves away. The lull with Camille will probably last from a few minutes to one-half hour and persons should not venture far from safe shelter. Hurricane Camille has begun to fill and will weaken quite rapidly as it continues northward through Mississippi at about 15 miles per hour tonight and Monday. Winds and seas will gradually diminish Monday as Camille moves away from the coast. Warnings will be discontinued Monday."

At 1 a.m. CDT on Monday, Aug. 18, a bulletin was issued at the time when Camille was battering the Mississippi coast and heading inland. It reported that hurricane winds were occurring from extreme southeast Louisiana eastward across the Mississippi coast with a few squalls to hurricane speed likely across coastal Alabama into northwest Florida. Tides were running ten to 20 feet above normal on the Mississippi coast and five to ten feet elsewhere from southeast Louisiana to Northwest Florida. It cautioned that several tornadoes were likely that night within 100 miles of the coast in the area of southeastern Mississippi eastward to Fort Walton Beach, Florida.

At 1 a.m., the center of the hurricane was located by New Orleans and other landbased

radars near latitude 30.6 north, longitude 89.5 west or 10 to 15 miles east of Picayune, Mississippi. Highest winds were estimated at 140 miles per hour near the center along the Mississippi coast. Keesler Air Force Base at Biloxi reported 20-foot tides and 125-to-150-mile per hour winds at 10:30 p.m. CDT the previous evening. A 3 a.m. bulletin substantially repeated the advisory.

At 5 a.m. CDT, Monday, Aug. 18, Advisory Number Nineteen was issued. It found the hurricane continuing to weaken, and predicted a more rapid weakening as the storm moved northward through Mississippi at about 15 miles per hour. An 8 a.m. bulletin said warnings along the northern Gulf coast would be discontinued at 11 a.m. CDT. Highest winds at that time were estimated at 80 miles an hour, tides were falling along the coast, and many areas were still inundated. Winds and tides were forecast to continue diminishing through the day. Heavy rains with local accumulations of five to eight inches were expected in northern Mississippi that day and evening, and heavy rain was predicted to spread into western Tennessee and western Kentucky that night and the following day.

Advisory Number Twenty was issued at 11 a.m. Monday, August 18 CDT. It reported the storm continuing to weaken as she moved northward through central Mississippi.

Warnings were discontinued along the northern Gulf Coast at 11 a.m. CDT. It reported tides falling along the coast, with many areas still inundated. It stated that winds and tides would continue to diminish that day and night.

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