SELECTION OF DATA FOR

TROPICAL CYCLONE RAINFALL STUDIES

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Rainfall which occurs during the passage of a hurricane or tropical storm center several hundred miles away may or may not be directly related to the passing tropical cyclone. Satellite remote sensing imagery may be used to determine the areal distribution of clouds associated with the tropical cyclone and reveal the areas where rainfall was directly attributable to such a storm. Satellite imagery, however, exists only from 1960 to the present, and is difficult to obtain for 1960 through 1968. No such record of the continuity of cloud coverage is available for earlier times. Without knowing if an area was covered by clouds which emanated from a tropical system, it is not possible to determine with certainty if rain which fell at a given place was the result of the passing tropical cyclone or of other local or extra-tropical causes.

Previous Studies

Previous studies of tropical cyclone rainfall have failed to address the problem of whether a given observation of rain actually resulted from a specific storm. Cry (1967) discussed the problem of wind reducing the effectiveness of rain collection devices but neglects the question of whether the given sample should be considered at all. Goodyear (1968) avoided raw climatological data by using the United States Army Corps of Engineers information whenever possible. For earlier times he draws his information directly from summaries of weather station records, but gives no explanation of how it is known that the rainfall is the result of tropical cyclones in either situation. The Corps of Engineers' storm rainfall reports also disclosed no statement on this topic.

Milton (1978) cites Schoner and Molansky (1956) and Miller (1958) as having the most sophisticated networks of data with which to work, but it appears that their methodologies for selecting data were no more advanced than others who wrote on the topic of tropical cyclone rainfall. Schoner and Molansky listed "Climatological Data" or "Hydrologic Bulletins" of the Weather Bureau, and Corps of Engineers as their sources, just as Goodyear did, and made no further statement regarding the selection of data.

Miller chose to discontinue tabulating data whenever the winds around the center of the storm dropped below hurricane force. This practice ignores any rain which results from tropical storms and a substantial part of the rain resulting from dissipating hurricanes. Miller also discussed the problems of rain-gauge effectiveness and the possibility of orographic and extratropical influences on hurricane rainfall. He stated that hurricane rainfall data from Florida are virtually free of orographic and extratropical effects. While the flatness of Florida certainly minimizes orographic effects, the statement regarding extratropical influences must be questioned. NOAA satellite imagery of Hurricane Gladys, September 23, 1975 (Fig. 1), shows what appears to be a middle latitude frontal system blending with the tropical cyclone.

Gentry (1964) is the only author found who discussed a means for determining the actual areas in which rain is falling in the vicinity of a hurricane or tropical storm. He cited the use of airborne radar for the purpose of studying the patterns of hurricane rainbands. Gentry's methodology is quite expensive, however, and, like the use of satellite imagery, cannot be applied to historical data.

Criteria for Determining Rainfall Source

When no direct means are available for identifying the source of a rainfall datum, other ways have to be found to determine if rainfall can be attributed to a tropical cyclone. Several assumptions were tested as reasonable cri-

teria on which to base such decisions. These assumptions were designed to provide a consistent set of criteria which could be applied in the absence of direct evidence. The results obtained by such criteria were compared to the conclusions derived from remote sensing imagery, and rainfall data from nineteen weather stations in and near the South Florida Water Management District, the area for which the storm rainfall was studied (Brandes, 1982) (Fig. 2).

Some Discarded Assumptions

Although the author's initial assumptions appeared to be consistent with known patterns of hurricane behavior, most of them were found to produce conclusions which were inconsistent with those derived from the satellite images. One assumption was that the shape of the area where rainfall was influenced by a tropical cyclone would be congruent with the shape of a smaller area defined by specific values indicating heavy rainfall and strong wind. It was found, however, that the data did not substantiate this, although a larger network of stations might yield a more conclusive pattern.

Another assumption was that if a station which reported no rainfall on a given day lies between an area of known tropical cyclone influence and another station which reported some rainfall, the rain which fell at locations beyond the dry station is not the result of the tropical cyclone. This assumption was based on the expectation that any station which is under the influence of a tropical cyclone should receive at least a small quantity of rain during a twenty-four hour period. It was found, however, that although a well developed, tightly formed hurricane, such as Allan, August 1980 (Fig. 3), will yield such a rainfall pattern, relatively dry storms with poorly developed circulation, such as Tropical Storm Amy on June 26, 1975 (Fig. 4), may pass some stations without dropping rain for twenty-four hour periods. A further difficulty is the quality of the raw data. Weather stations do not all record their data at the same time of day. Thus, rain which falls simultaneously in two different locations may be attributed to different days and rain which falls on adjoining days may be attributed to the same day.

A third assumption was that for any location which is known to receive precipitation from a tropical storm or hurricane on at least one day, the period of time in which the place was influenced by the storm will extend neither earlier than the last preceding dry day nor later than the next following day without rain. Widely spaced rainbands and erratic rainfall patterns of some storms impair the utility of this criterion as well, particularly for relatively dry storms. The quality of the data also presents another problem. Occasionally the passage of a hurricane may disable the rain gauge or prevent the observer from recording each day of rainfall. Several days of rainfall may go unrecorded or may be reported in a single observation. Published summaries of climatological data normally contain notes when cumulative quantities for several days are reported, but there appear to be unnoted instances of such reports as well, as for example at Okeechobee in 1939 when no rain was recorded for two days while the eye of a hurricane passed over the area , but more than three inches was recorded for the following day when the storm center was several hundred miles away.

An Effective Procedure

Wide variability in the size, shape, intensity, and rainfall patterns of hurricanes and tropical storms precluded the prescription of any rigidly defined methodology for determining whether a given observation of rainfall was the result of a tropical cyclone system, at least within the confines of the study area. Expanding the study area to include the entire Gulf of Mexico, Atlantic Ocean coasts of North America, and islands of the Caribbean region might, however, provide some more definitive statements on this topic.

The most effective procedure which was tried in this study was to plot the daily rainfall values on maps of the study area and to examine the spatial and temporal distributions of rainfall across the study area for the several days while each storm passed. Prior to the arrival of a hurricane or tropical storm, there were usually several days when rain was reported at few, if any, stations. If rain was found at a majority of stations, the quantities would tend to be small and randomly distributed across the area. With the approach of a tropical system, rainfall generally increased in frequency and quantity for several days before returning to pre-storm levels.

The principles of spatial and temporal continuity apply to tropical cyclone rainfall but not in the rigidly defined manner which was prescribed by earlier assumptions. If one or several stations report no rain on a given day, those stations and others yet more distant from the storm center may still be judged to be under the influence of the tropical system if the proximity of the storm and the general pattern of circulation around it can be used to explain the pattern of rainfall observations.

In most instances, if rain was falling at a given location and there was a tropical weather system centered within 300 miles of the site, the rain could be attributed to that storm. The 300-mile maximum radius conforms to the limit of the area for which Miller (1958) selected data. Miller, however, used that distance as a rigid arbitrary limit while the present findings suggest only that it is an approximate median of the radius of the area that would be influenced by a hurricane or tropical storm. This radius may actually vary from 150 to 600 miles from the storm center, and therefore must be determined individually for each storm. The use of any predetermined or arbitrary limit to the distance from a tropical cyclone center for which data will be accepted would yield misleading results in most instances.

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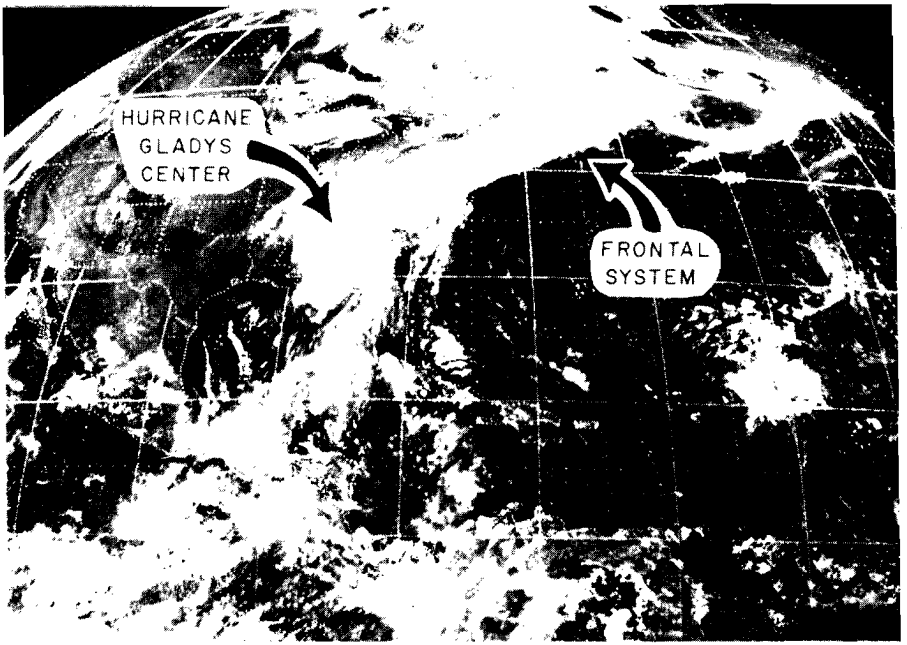
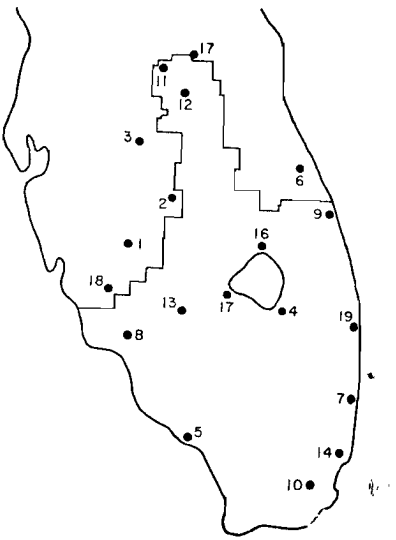


Fig. 1. Hurricane Gladys, September 13, 1975.

FIGURE 2

WEATHER STATIONS

1 Arcadia
2 Avon Park
3 Bartow
4 Belle Glade
5 Everglades
6 Fellsmere
7 Fort Lauderdale
8 Fort Myers
9 Fort Pierce
10 Homestead
11 Isleworth
12 Kissimmee
13 La Belle
14 Miami
15 Moore Haven
16 Okeechobee
17 Orlando
18 Punta Gorda
19 West Palm Beach



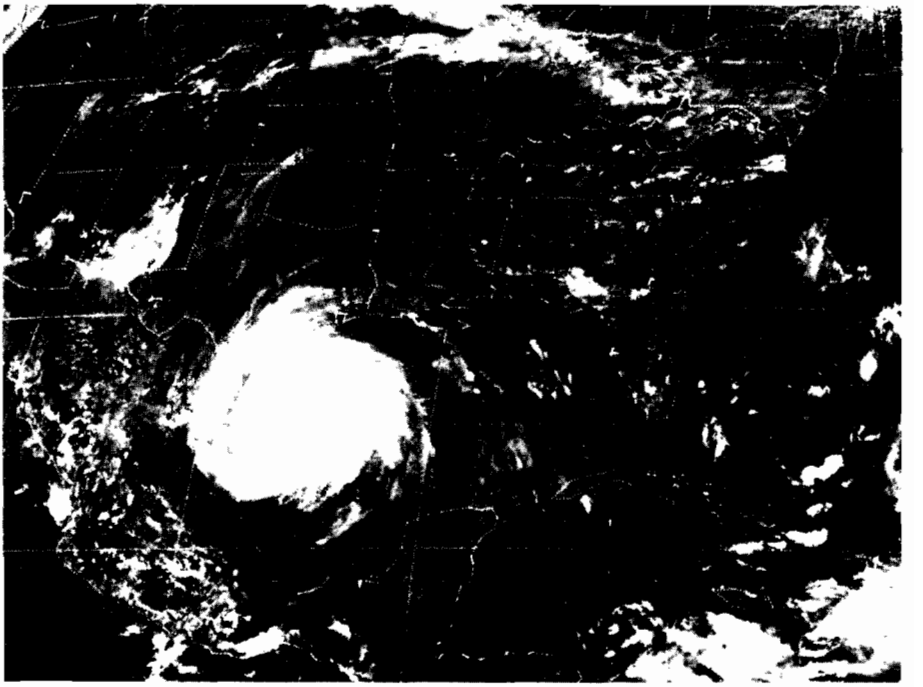


Fig. 3. Hurricane Allen, August 1980.

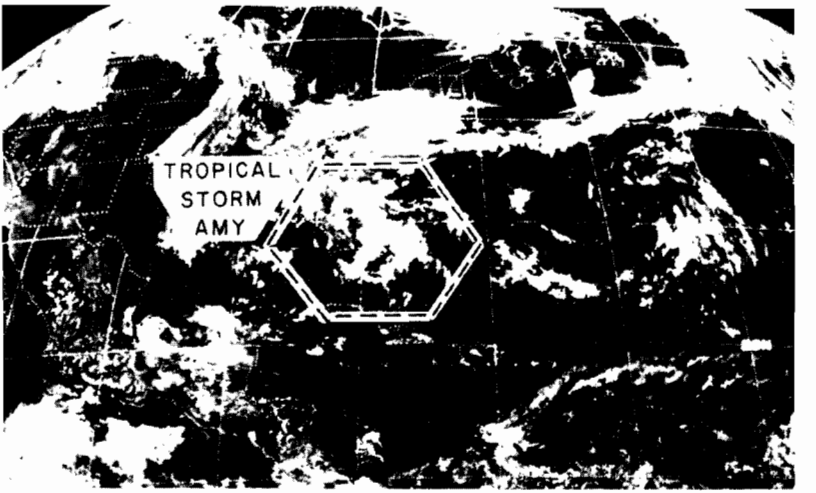


Fig. 4. Tropical Storm Amy, June 26, 1975