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Note on ITCZ Wave Disturbances and Formation of Tropical Storm Anna

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ABSTRACT—An examination of Applications Technology Satellite 3 photographs of the Atlantic intertropical convergence zone (ITCZ) for the period May through July of 1969 has revealed an excellent case of ITCZ wave instability that was responsible for the formation of tropical storm Anna. Photographs are presented to emphasize the argument that wavelike perturbations in the ITCZ, independent of easterly disturbances, are capable of amplifying, breaking, and shedding vortexes of hurricane proportions. Observational evidence of this means of hurricane genesis strongly suggests the need for a theoretical treatment of the problem.

1. INTRODUCTION

It has been properly recognized by tropical meteorologists for some time that Riehl's (1945) classical easterly wave model cannot be used to explain the occurrence of all tropical disturbances. In fact, several individuals have pointed out (e.g., Simpson et al. 1968) that the easterly wave model has been grossly overworked. With the advent of a meteorological satellite program in the 1960s, a better appreciation of the role played by the easterly wave in tropical storm formation has been gained. More recently, Applications Technology Satellite (ATS) cloud photography has allowed better observational study of tropical disturbances and the evolution of tropical storms. Such photographic documentation has shown that many tropical disturbances cannot be initially associated with an easterly wave, but actually appear as convective disturbances in the intertropical convergence zone (ITCZ). The January 1970 Global Atmospheric Research Program (GARP) technical report has termed these and similar convective disturbances "cloud clusters," which may be associated with synoptic scale wave disturbances in the ITCZ. Frank (1970), in his census of 1969 Atlantic tropical systems, appropriately points out that the difficulties in defining and studying ITCZ disturbances are due to the virtual nonexistence of conventional upper air data. He further notes that the inability to treat the ITCZ disturbance was one of the more unsatisfying aspects of the census.

As previously mentioned, tropical disturbances can initially occur, in the absence of an easterly wave, as cloud clusters in the ITCZ. If, for example, a wave disturbance in the ITCZ grows to a sufficiently large amplitude, then a horizontal wave pattern can be induced in the easterly flow, but the disturbance is not initially attributable to an easterly wave. This simple argument is essentially the reverse of that used by Frank (1969) in his discussion of the "inverted V" cloud pattern, when he proposed that a sufficiently large-amplitude easterly wave could distort the ITCZ cloudband.

The findings presented in this short note, based on a study of ATS 3 cloud photography for the summer of 1969, show excellent photographic documentation of synoptic scale wave disturbances in the Atlantic ITCZ that appear to be responsible for the formation of tropical storm Anna. The apparent development of cyclonic rotation in a cloud cluster is noted almost simultaneously with its separation from a well-developed ITCZ wave disturbance. It is proposed that the existence of appreciable cyclonic shear in the horizontal wind field was at least partly responsible for the breaking of the ITCZ wave once a large amplitude was achieved; however, the absence of adequate rawinsonde data prevented a ready examination of the importance of this or any other argument. No attempt was made to estimate the wind field through photogrammetric study of cloud motions on ATS picture sequences.

2. ITCZ FEATURES DURING BOMEX

ATS 3 cloud photographs taken during the summer of 1969 were reviewed because of the author's interest in the simultaneous collection of Barbados Oceanographic and Meteorological Experiment (BOMEX) data and the possible occurrence of organized patterns of mesoscale convection. This activity provided an opportunity to study the general features of the Atlantic ITCZ for the period May through July of 1969. Most striking in the review of the photographs was the daily persistence of the ITCZ cloudband from about 5° to 10°N oriented generally east–west across the North Atlantic. Breaks in the ITCZ were noted during the period with interruptions in the continuity of the convective cloudband particularly noticeable near the African and South American continents. Occasionally, weak to moderate cloud clusters were identifiable; but, for the most part, significant bright clusters were not observable until the latter part of July. Also, the existence of any significant synoptic scale waves propagating westward along the ITCZ did not occur until late July. Figure 1 gives a representative view of ITCZ cloudiness on July 13 with little or no indication of wave development. Basically,

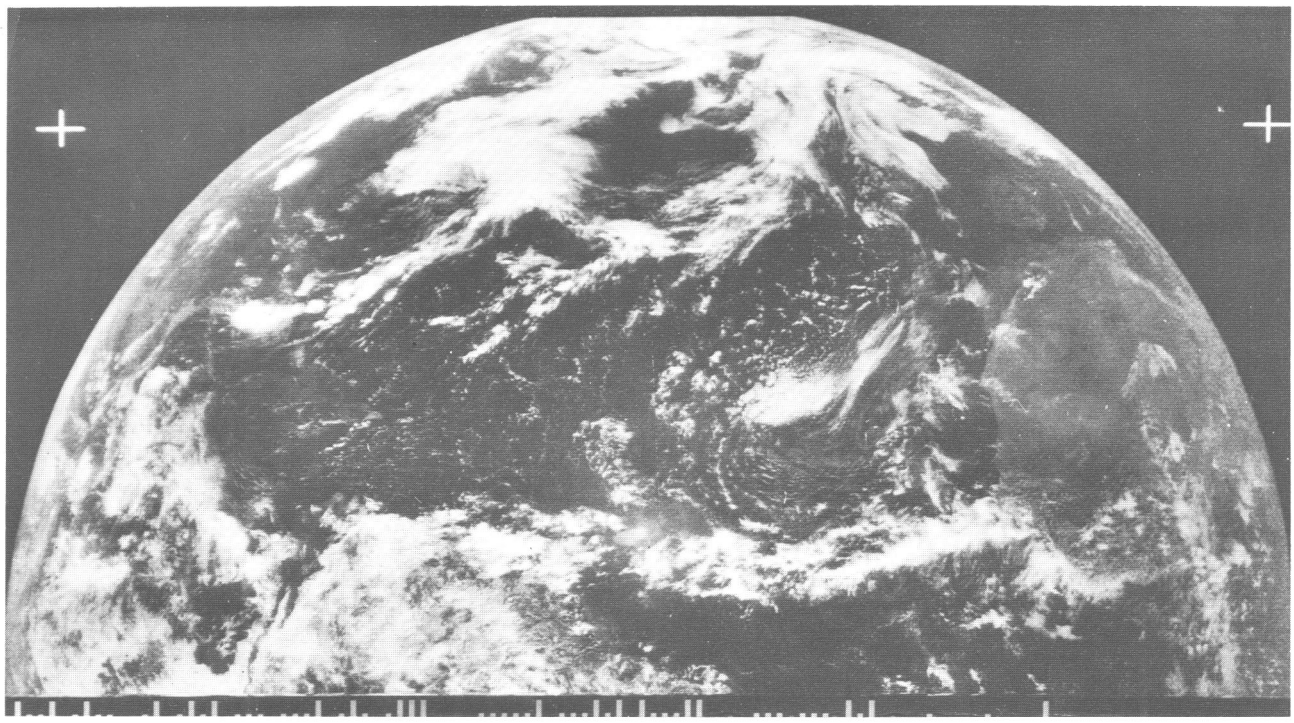

FIGURE 1.—ATS 3 view of ITCZ cloudiness over the Atlantic in July 1969 prior to its development of a synoptic scale wave pattern. The ITCZ cloudband is located within the zonal strip 5°–10°N.

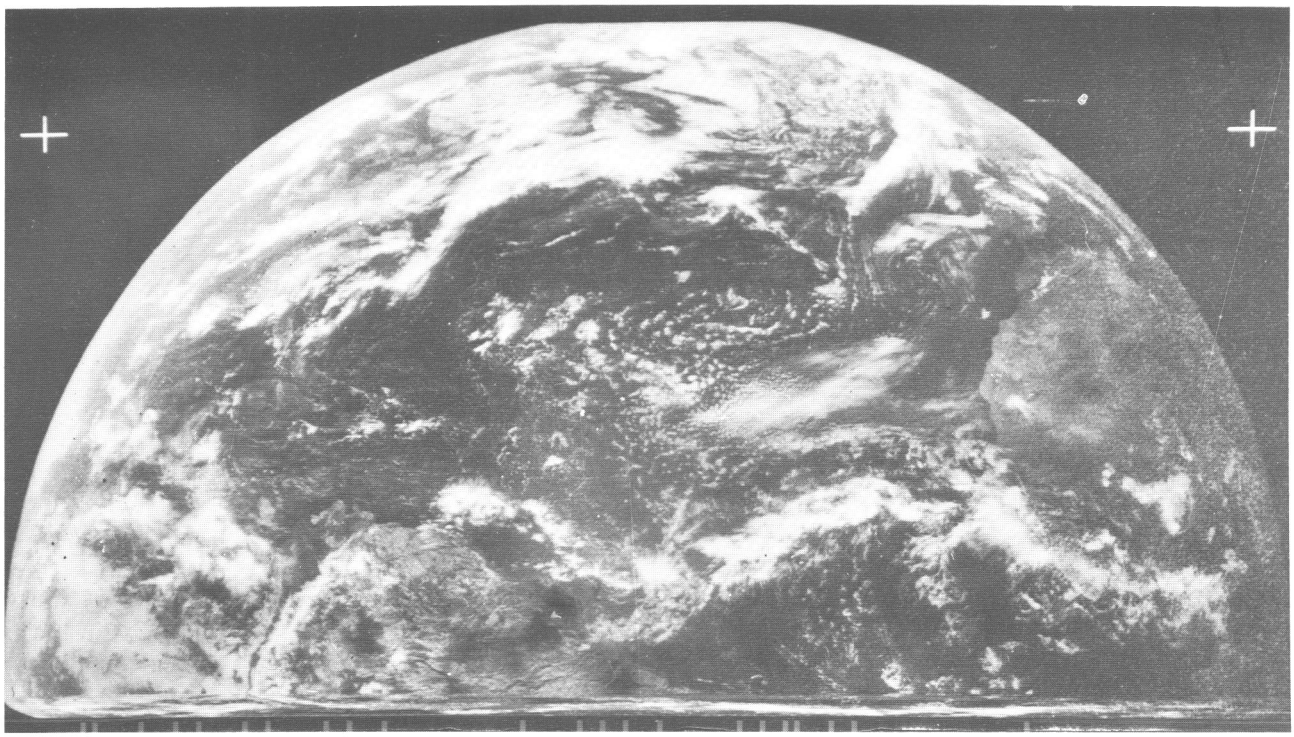

FIGURE 2.—Photograph of the first major synoptic scale wave disturbance in the Atlantic ITCZ for the summer of 1969. Wave amplitude extends from 5° to 15°N.

from the west coast of Africa to the northern part of South America, the convective cloudband shown is continuous with east–west orientation. Some southward displacement of the cloudline can be noted along the coast of Africa.

The first significant synoptic scale wave in the ITCZ for the summer of 1969 had developed by July 22. This wave disturbance, shown in figure 2, had a wavelength of approximately 3000 km and was propagating toward the west. Concurrently with the development of this wave disturbance, an increase in cloud cluster intensity was noted. This intensity represented the most convective activity along the ITCZ to date during the period of study.

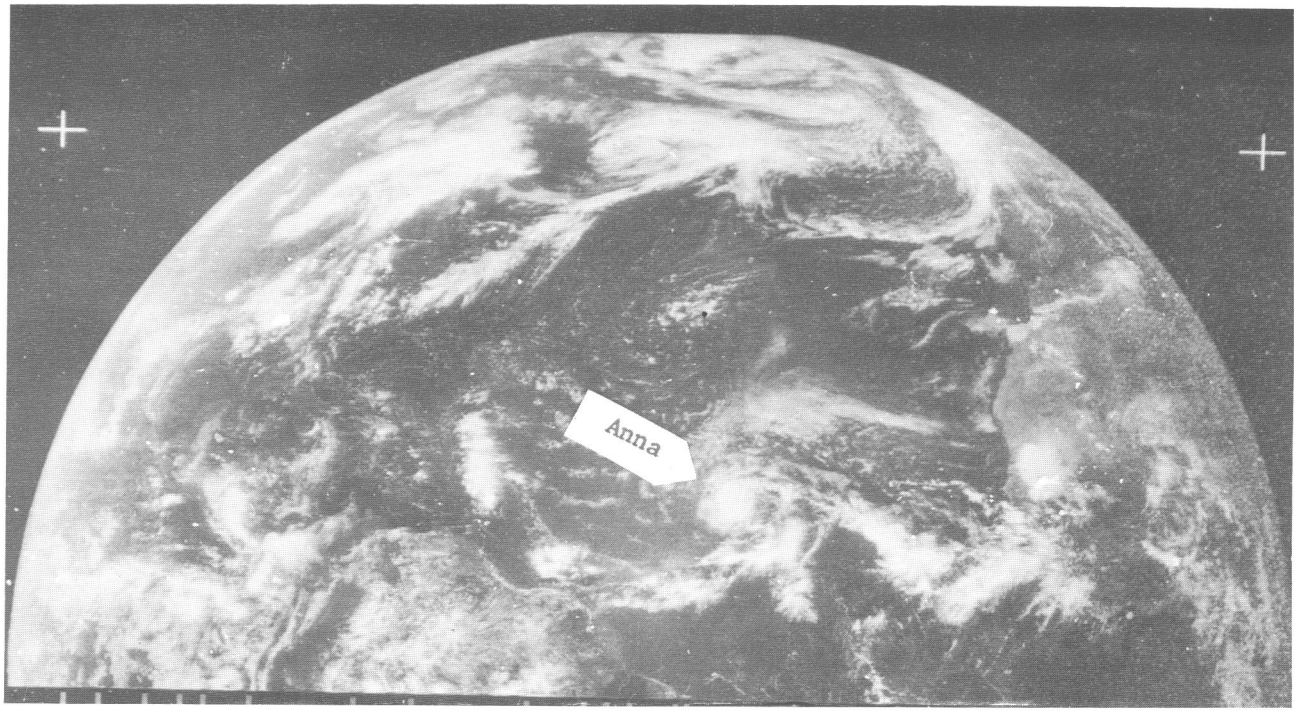

FIGURE 3.—A view of a breaking wave in the Atlantic ITCZ and the development of tropical storm Anna at the wave crest.

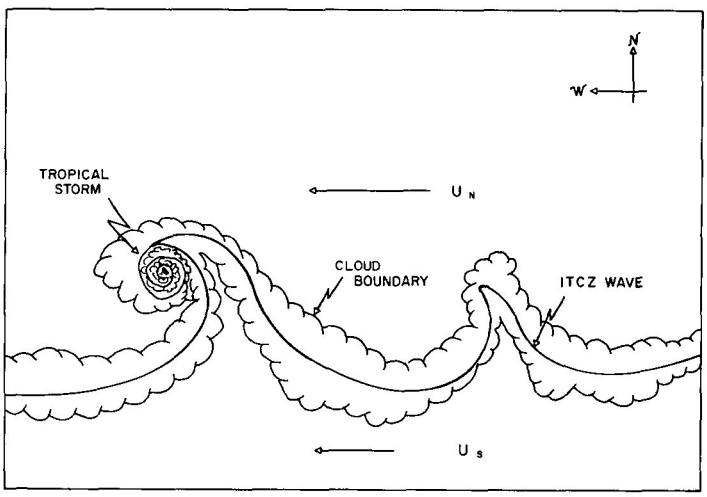

FIGURE 4.—Schematic of a breaking ITCZ wave, supposedly under the stress of horizontal cyclonic wind shear present in the easterly flow, with associated tropical storm or vortex formation.

3. THE DEVELOPMENT OF TROPICAL STORM ANNA

After the first occurrence of major wave instability in the ITCZ, cloud cluster features became more enhanced. By July 27, a tropical depression was located at 10°N, 37°W in association with an ITCZ wave disturbance that originated near the African continent. The following day, this depression was elevated to tropical storm Anna and is shown in figure 3. From the series of pictures viewed, a schematic is presented in figure 4 portraying the position of Anna with respect to the wave in the ITCZ. The breaking of the wave at its crest under the action of appropriate cyclonic shearing stresses could have initiated cyclonic rotation in the pre-existing cloud cluster. As the wave breaks down under shearing forces, a vortex is shed into the easterly flow. Figure 5 shows a series or train of waves observed on the next day with Anna separating from the ITCZ. These waves had an estimated velocity of 250 n. mi./day toward the west. It is noteworthy that in these wave disturbances the most significant convective development is occurring in the most northern extension of the wave (10°–15°N), probably in association with an inverted trough in the pressure field. The southern part of the waves (5°N) shows no indication of cloud cluster enhancement or rotational development.

Figure 6 shows Anna on July 31 completely separated from the ITCZ and moving northwestward, apparently to the right of the easterly tradewind flow. An interesting wake of cloud material can be noted trailing off the right flank of the storm system to the southeast toward the disturbed remnants of the ITCZ. The storm never achieved hurricane intensity following its exodus from the influence of the easterly trades. According to Sugg and Pardue (1970), Anna's movement was toward an upper level cyclone that formed between Bermuda and Puerto Rico. This synoptic feature is recognized as one that tends to inhibit tropical cyclone growth and intensification to the hurricane stage.

4. SUMMARY

Photographic evidence of ITCZ wave instability and its apparent role in tropical cyclone development has been presented. ATS 3 photographs of tropical storm Anna of 1969 have been studied, and it appears that the origin of the storm is related to the breaking wave crest of an ITCZ disturbance. Existing cyclonic shear in the horizontal wind field may have been responsible for the breaking of

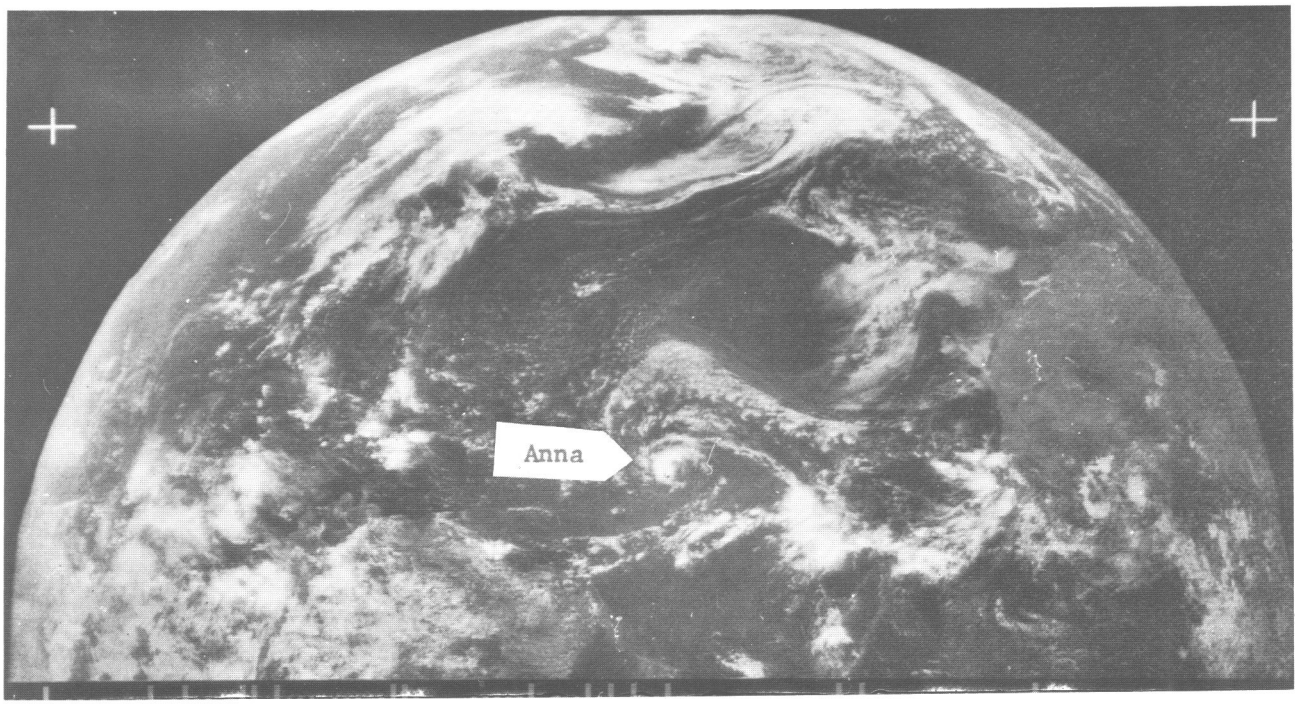

FIGURE 5.—Photograph of a series of wave disturbances occurring in the Atlantic ITCZ concurrently with the separation or shedding of tropical storm Anna.

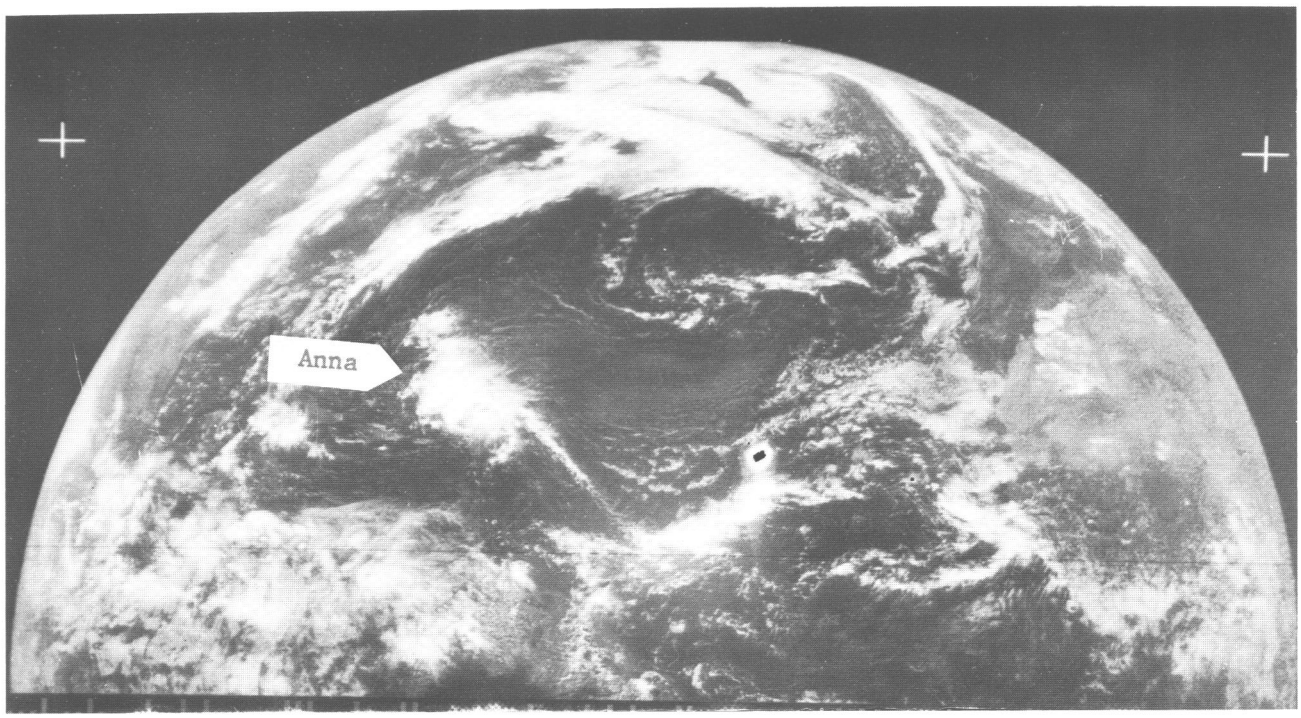

FIGURE 6.—A view of tropical storm Anna fully separated from the Atlantic ITCZ and moving northwestward.

the wave and the forming of a tropical cyclone. The vortex shed by the decaying wave train propagated to the northwest as tropical storm Anna but never achieved hurricane intensity.

Any tropical cyclone resulting from a breaking ITCZ wave may later intensify or weaken depending upon the conditions of the storm's new atmospheric environment. Whether or not the tropical storm develops into a hurricane appears immaterial to the generating mechanism proposed here. An ITCZ wave that is amplifying, breaking, and shedding a cyclonically rotating vortex is an apparent means of hurricane genesis. Although beyond the scope of this note, a theoretical study of this problem is clearly in order.

The contents of this note are rather phenomenological and in places incomplete, but appropriate explanations of ITCZ wave instability and its importance in hurricane formation demand more and better data collection in the Tropics. This, of course, has been one of the major concerns in the GARP Atlantic Tropical Experiment program planning.

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