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EASTERN PACIFIC HURRICANE SEASON OF 1970

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ABSTRACT

A statistical résumé of the season is presented, and a tentative climatology is proposed, based on 5 yr of operational satellite coverage. Basic data were increased through more reconnaissance flights and satellite pictures. No direct storm casualties or damage from storm winds or seas were reported. Casualties and damage resulting from the Arizona flood disaster were indirectly related to tropical storm Norma. The chronicle of hurricanes and tropical storms deals mainly with the relationship of the data to hurricane intensity and to physical processes within the various tropical cyclones.

1. INTRODUCTION

The season opened on May 30 with the disturbance that developed into hurricane Adele and ended on November 8 when the dissipating cloud spiral generated by Selma was photographed by satellite south of Baja California (fig. 1). A somewhat longer season, beginning with the rapid increase in intertropical confluence and convection in mid-May and ending with a gradual fadeout during November, and perhaps part of December, probably had tropical cyclone potential. There was a proliferation of early season storms and then a lull in activity in September. No attempt has been made to relate this change to changes in the middle-latitude general circulation.

There were four hurricanes; two, Lorraine and Patricia, had winds near 100 kt for a time. One ship reported 85-kt winds and 45-ft wave heights in Francesca. With Adele, 65-kt winds were reported by reconnaissance on June 3, after satellite pictures revealed dissipation processes were operating. Hurricance intensity had prevailed in Adele for most of the preceding 3 days; this condition was indicated by a May 31 ship report of 60-kt winds.

Names were applied to 14 other tropical cyclones by evaluating them operationally as storms. Dolores probably was not a storm, since it dissipated within 24 hr after discovery. The name Ione was applied to two discrete cyclones with centers 300 n.mi. apart. The first Ione was quite short-lived; no cirrus production was observed by satellite. A ship reported winds of 48 kt with rough seas, and surface wind and pressure information indicated a closed circulation more than 100 n.mi. in diameter.

Three cyclones were treated operationally as depressions only. Two could have been weak tropical storms, but classification depended on arbitrary wind estimates based on satellite pictures.

All of the listed cyclone systems can be described with reasonable confidence as having been warm-core types. All originated near the north edge of or in the principal intertropical trough prevailing at a given longitude. A second intertropical trough, generated by a recurving Southern Hemisphere push, was present to the south in some instances (Fujita et al. 1969). None of the storms had any apparent relation to cutoff Lows of the middle-latitude westerlies.

Hurricane intensities were listed in 34 operationa advisories; tropical storm intensities were listed in 202l Depression intensity was reported in 118 bulletins. There were 16 hurricane days and 72 tropical storm days, this count included 2 days for each day with two storms. Monthly distribution is given in table 1.

Table 2 is a tabulation of hurricanes and tropical storms by month of beginning for each of the 5 yr of full operational satellite coverage. The averages of 5.4 hurricanes and 10.0 tropical storms appear to be reasonable approximations to an annual normal. Such a short period of record makes approximation of the normal uncertain, as does the lack of precise knowledge of actual maximum sustained winds in cyclones of borderline tropical storm or hurricane intensity.

2. STORM EFFECTS

No report of casualties caused directly by hurricane winds or seas reached San Francisco. Direct property damage appears to have been light. Only two storms were tracked onto Mexico. One, Eileen, probably had 40-kt maximum winds upon landfall south of Mazatlán. The other, Orlene, which satellite picture continuity suggested moved onto the Mexican mainland, may have caused winds of about 60 kt along the coast of the Gulf of Tehuantepec. For the beaches of southern California, the hurricanes generated the usual problems of forecasting high surf.

The casualties and damage (22 deaths and over $1 million) in the Arizona flood disaster of September 4–6 were caused by a combination of circumstances of which tropical storm Norma was an essential part. While more than 600 n.mi. south of the flood area, Norma fed southerly winds and unstable air carrying extraordinary amounts of moisture into the extratropical storm directly responsible for the rains.

Washouts, mud slides, and other flood effects in Mexico during September 24–26 were related to a northward push of the intertropical trough (Fujita et al. 1969) that caused the flow of moist, convergent southwest winds ranging from 15 to 30 mi/hr against the rugged terrain. The northward push spawned cyclone number 17, which, though

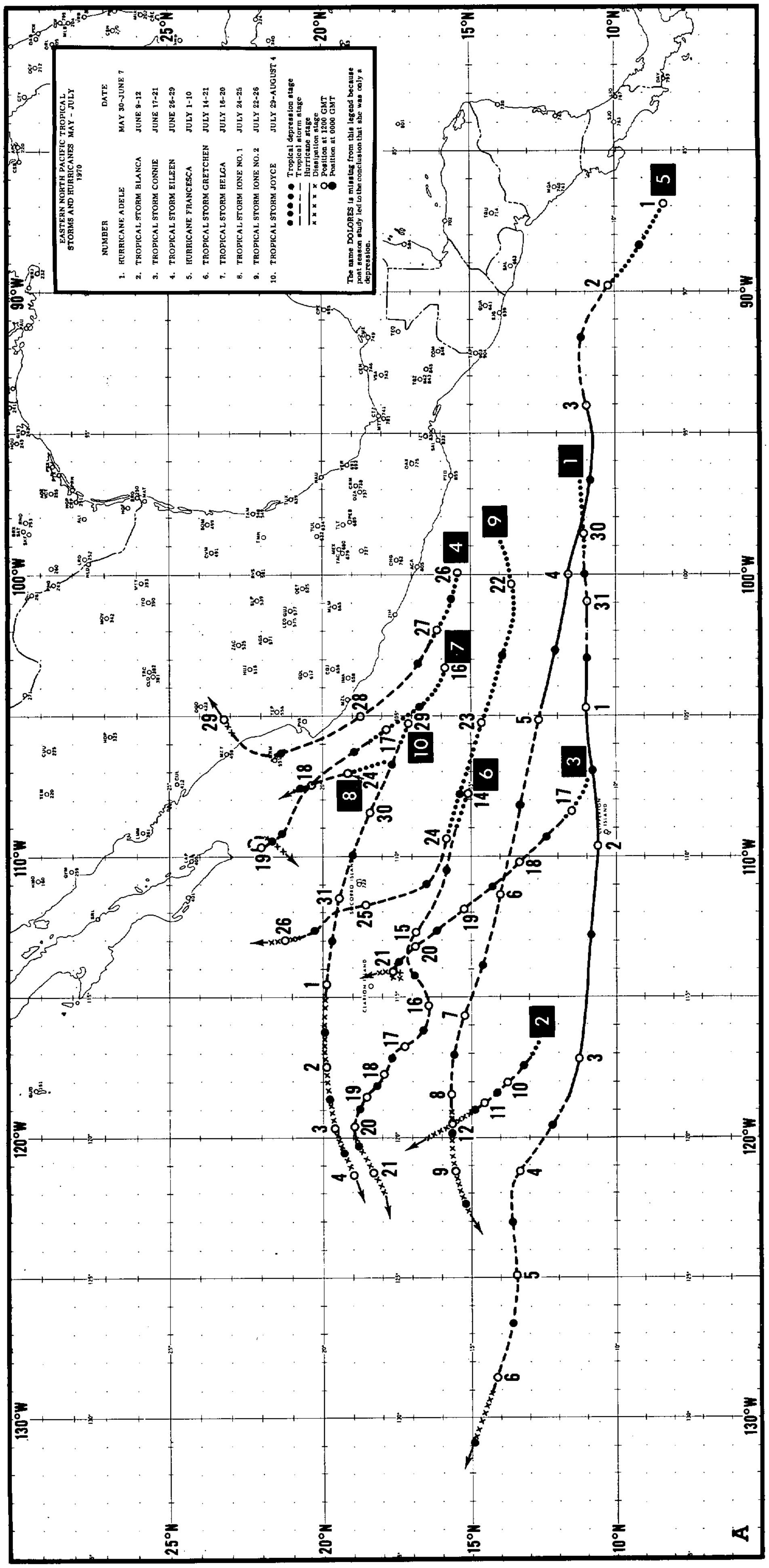

FIGURE 1.—Eastern North Pacific tropical storms and hurricanes during (A) May–July and (B, p. 288) August–November 1970.

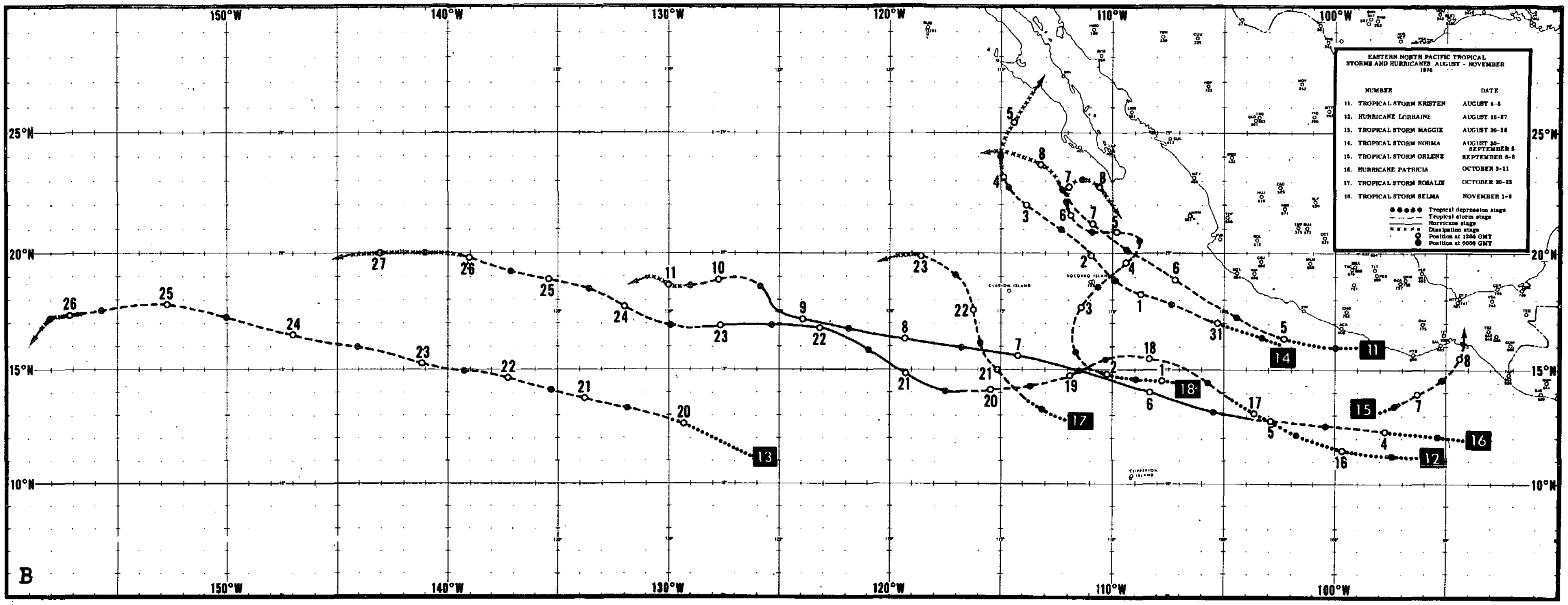

FIGURE 1.—Concluded.

TABLE 1.—*Monthly distribution of tropical storm and hurricane days in the Eastern Pacific in 1970*

Disignation	May	June	July	Aug.	Sept.	Oct.	Nov.	Totals
Hurricanes	1	3	3	4	--------	5	--------	16
Tropical storms	1	14	22	18	6	6	5	72
Combined	2	17	25	22	6	11	5	88

Each day with two storms is counted as 2 days.
Each day is counted according to the higher intensity of the cyclone involved.

TABLE 2.—*Tabulation of hurricanes* (Hu) *and tropical storms* (TS) *by month and year in which they began in the Eastern Pacific*

Year	May Hu	May TS	June Hu	June TS	July Hu	July TS	Aug. Hu	Aug. TS	Sept. Hu	Sept. TS	Oct. Hu	Oct. TS	Nov. Hu	Nov. TS	Totals Hu	Totals TS	Totals Combined
1966			1				4		2	4		2			7	6	13
1967			1	2		4	2	2	1	2	2	1			6	11	17
1968				1		4	3	5	2	1	1	2			6	13	19
1969					1	2	1	1	1	3	1				4	6	10
1970	1			3	1	5	1	3		1	1	1		1	4	14	18
5-yr total	1		2	6	2	15	11	11	6	11	5	6		1	27	50	77
Annual averages															5.4	10.0	15.4

treated operationally as a depression, may have been briefly a weak tropical storm. Winds in the immediate vicinity of the depression were a small factor in the rains. This same depression, through what was interpreted to be an illusion of ATS 3 (applications technology satellite) perspective, seemed to become a rather intense circulation over approximately a 2-hr period; after nearly an hour, it resumed its original configuration as a loosely organized spiral of clouds.

3. USE OF THE BASIC DATA

Reconnaissance aircraft and satellites provided most of the basic information. There were improvements in the quantity and quality of data from both in 1970. A partly successful effort was made to stimulate more special reporting by ships. Synoptic and aviation reports from land stations in Mexico were quite limited; but San Francisco received radiosonde, rawin, and pibal reports primarily from stations in northern Mexico. Cirrus-level winds derived from geostationary satellite observations were furnished occasionally by the National Environmental Satellite Service (NESS), NOAA, for a few widely scattered points in the storm area.

Research by Fujita et al. (1969) using low-level satellite winds provided a useful model for streamline analysis; instead of satellite winds, available ship reports and APT (automatic picture transmission) photographs from ESSA and ITOS (improved TIROS operational satellite) photographs are used. This analysis was made when there were adequate data over a 12-hr period. It was rarely possible to identify more than three or four stages of equatorial anticyclones, and only a few of the many identifiable surges from the Southern Hemisphere could be linked to tropical storm generation. The streamline analysis served as a qualitative estimate of the rate of low-level inflow and in some cases provided clues to the entry of cool surface air, from over cold water to the north, into the inner storm circulation. Other clues to the entry of cool surface air into the hurricane circulation were sought by inspecting satellite pictures of the south edge of the semipermanent summer stratus shield west of Baja California for evidence of disturbance by the storm (Denney 1969). Cool surface air was assumed to be entering the fringes of the hurricane, with a cross-isobaric component of 20° or so, as soon as the outer storm circulation started to break up the edge of the stratus or change its character.

Upper air contour analyses were extended toward the area of concern as far as was justified by the reported data, but they were rarely of much use in the diagnosis or prognosis of high-level outflow over an existing or suspected cyclone. The high-level outflow from an area, as seen on ESSA 8 and ITOS 1 pictures of cirrus, and its changes with time provided the only information available operationally for solution of this problem. Cirrus outflow, requiring low-level, warm, moist inflow and a chimney (or chimneys) of rising air for its manisfestation, is limited in its usefulness as a predictor of initial development because the development may be well underway when the cirrus outflow is first seen.

Storm steering by the environment could not be solved either subjectively or objectively without observations on which to base a determination of mean environmental motion. Recent movement of a storm provided the best available index to the motion of the environment near its area of origin. Extrapolation and climatology were supplemented by subjective evaluation of environmental motion. The Navy's HATRACK system (Renard and Levings 1969) was also used when data were adequate for a reasonably firm analysis, a condition that could be met only occasionally as the storms moved north of about 20°N. (Computations of HATRACK parameters were done at Monterey, Calif.)

A reconnaissance fix of location, size, and intensity was usually available for the 2100 GMT advisories issued more than 24 hr after a cyclone was first recognized. No investigative missions were planned for disturbances before they developed into depressions. Missions to investigate dissipating depressions were not planned, since experience has shown they rarely regenerate in the Eastern Pacific. Reconnaissance reports, when available, ordinarily were the basis for advisories.

A total of 54 reconnaissance missions were flown for 61 storm fixes or negative cyclone activity reports. The U.S. Air Force used WC–135 aircraft for 29 missions and, later in the season, WC–130s for three missions. The U.S. Navy flew WC–121 aircraft on 22 missions. Aircraft were well instrumented and manned by experienced hurricane reconnaissance specialists. The WC–135 aircraft had long range; one hurricane fix was made in the deep Tropics at 11.8°N, 101.3°W. Navy WC–121 aircraft were slower and had shorter range, but much better tolerance for turbulence than the WC–135s. The tolerance of WC–121 aircraft for turbulence made low-level hurricane penetration feasible; observations of storm winds and seas were made from as low as 500 ft. When turbulence was not severe, some Air Force WC–135 aircraft descended to low altitudes to get a closer view of the sea and to determine winds to fix the center of a weak storm.

APT photographs from ESSA 8 and ITOS 1 were received locally at San Francisco directly from the satellites; forecasters thus had immediate access to the information. The NESS in Suitland, Md., provided advice on the interpretation of the photographs, using telephone and teletypewriter for direct communication, and also relayed information derived from ATS 1 and ATS 3 pictures on the intensity and position of storms in the area. The afternoon APT photographs from ITOS 1, not available in earlier years, proved quite useful for noting trends in the development or dissipation of storms during the 5- to 6-hr. interval between ESSA 8 and ITOS 1 pictures. When the pictures contained clear views of geographic points, precision gridding could be used to detect storm movement. Occasionally, the National Hurricane Center (NHC) at Miami, Fla., provided support to the San Francisco WSFO (Weather Service Forecast Office), using ATS 3 pictures and its extensive tropical analysis as information sources.

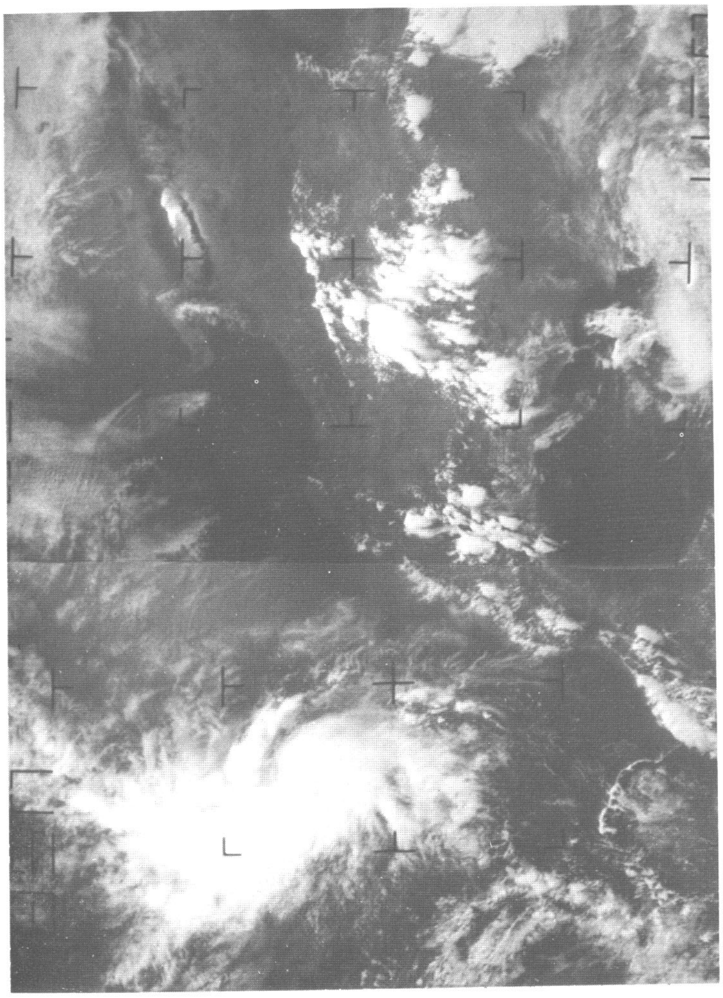

FIGURE 2.—ITOS 1 mosaic, orbit 1607, on May 31, 1970, depicting Adele (a young hurricane) in the foreground.

4. CHRONICLE OF HURRICANES AND TROPICAL STORMS

Information that had a decisive effect on forecasts will be mentioned, in so far as practicable, in discussions of the various cyclones, storms of unusual interest, and the hurricanes. These data frequently provided a basis for making judgments as to the physical processes affecting storm intensity but unfortunately were rarely useful for indicating change in storm movement in advance. Conclusions as to physical processes will be mentioned; details of storm tracks not discussed can be seen on figure 1. The tracks are smoothed to fit daily 1800 GMT and other positive fixes.

Special credit is due the hurricane reconnaissance meteorologists of the U.S. Navy and the U.S. Air Force, whose "detailed eye reports" and "postflight summaries" have been cited extensively.

HURRICANE ADELE

A disturbance marked by a cloud mass beginning to assume vortex shape was seen on satellite pictures near 11°N, 100°W, on May 30; this disturbance developed into an intense tropical storm in less than 24 hr. Ships in the vicinity of the cloud mass reported nearly calm winds on the 30th. The existence of intense tropical storm (or hurricane) Adele was brought abruptly to attention by the 1500 GMT May 31 report from the *Chevron Brussels* at 11.0°N, 102.1°W. The ship estimated winds of 60 kt and reported high seas and a pressure of 992.5 mb. A satellite picture taken 6 hr later (fig. 2) showed a storm that had just reached hurricane intensity.

Initially, the storm moved toward the west at a speed of 10 kt, accelerated to 20 kt for a time on June 2, then decelerated and started moving toward the west-northwest on June 3. Because of the irregular movement of the storm during that period, extrapolation was a poor tool for estimating storm position between satellite fixes; information from ships was not definitive.

U.S. Air Force reconnaissance provided center position fixes and storm intensities at 1800 GMT on June 3 and 4, and the U.S. Navy provided a fix on June 5. Maximum winds measured by reconnaissance on June 3 were 65 kt; then there was weakening to 50 kt on June 4 and to 40 kt on June 5. Only a partial eye wall was found by reconnaissance on June 3; there was a trend toward further disorganization after June 3 that ended in total dissipation late on June 6.

Analysis of the satellite pictures, the report from the *Chevron Brussels* on May 31, and the daily reconnaissance and concurrent pictures that started on June 3 led to the conclusion that Adele was a hurricane from shortly after the time of the ship report at 1500 GMT on May 31 until 1800 GMT on June 3. Maximum winds probably reached 75 or 80 kt late in the day on May 31 and on June 1.

An ESSA 8 picture on June 3, about concurrent with the reconnaissance report, indicated little cirrus production; the eye and eye wall were mostly uncovered. The radius of the eye wall was about 20 n.mi.; reconnaissance found the maximum 65-kt winds about 36 n.mi. east-northeast of the center, which was consistent with the diagnosis of a weakening trend having begun earlier (Colón 1963).

TROPICAL STORM BLANCA

The disturbance that became tropical storm Blanca was first discovered near 13°N, 115°W, on the ITOS 1 pictures at 2211 GMT on June 8. The storm continued to strengthen; tropical storm intensity and winds up to 45 kt were estimated from satellite pictures taken about 24 hr later.

The storm moved northwest at 5 kt; fixes by U.S. Navy reconnaissance on June 10 and 11 (showing maximum winds of 50 and 35 kt, respectively) established this movement. Continued dissipation of the storm was observed by satellite on June 12 and 13; movement toward the north-northwest was slow.

TROPICAL STORM CONNIE

The disturbance that became tropical storm Connie appeared near 10°N, 100°W, on June 13 near the location where Adele was first seen 2 weeks earlier. Maximum winds were estimated at 40 kt around a center at 12°N, 109°W, from a 1700 GMT June 17 ESSA 8 picture, after the westward-moving disturbance had intensified abruptly to tropical storm intensity. Connie then moved slowly northwest. During daily 1800 GMT reconnaissance of the storm, maximum winds were clocked at 45 kt on June 18 and 19 and at only 35 kt on June 20. The Air Force flew reconnaissance on the 18th and 20th; and the Navy, on the 19th. The ITOS picture of June 19 (fig. 3) showed that organization of the storm was loose. Dissipation was about complete, and the storm had stalled about 100 n.mi. southeast of Clarion Island when last seen on satellite pictures of June 21.

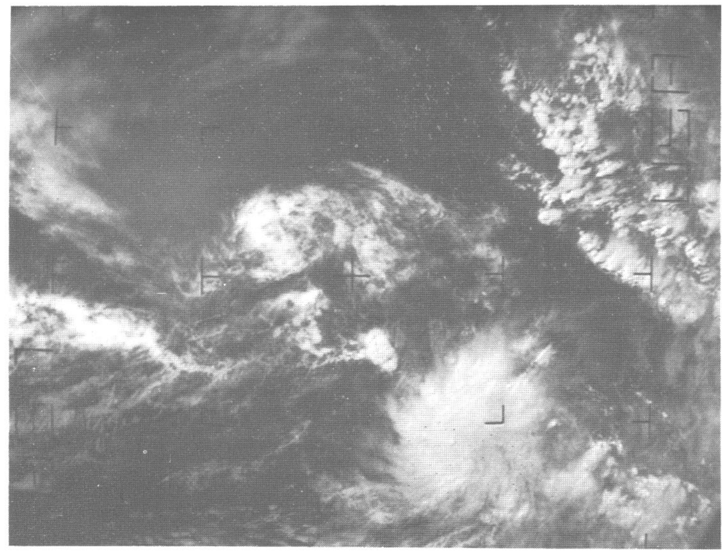

FIGURE 3.—ITOS 1 picture, orbit 1845, on June 19, 1970, showing Dolores (judged later to have been only a depression 600 n.mi. south of Cape Corrientes, Mexico) in the right foreground and Connie (a weak storm 600 n.mi. northwest of Dolores) just northwest of the center fiducial point.

TROPICAL DEPRESSION DOLORES

To forecasters, Dolores was one of three exasperating problem storms of the 1970 season. (The other problems were the unusual movement of tropical storm Orlene and the dual nature of Ione.)

Extensive cirrus outflow about 5° in diameter, seen on the ESSA 8 picture of 1647 GMT on June 19 in the vicinity of 10°N, 104°W, was the basis for issuing depression bulletins. A clear picture from ITOS 1 at 2219 GMT (fig. 3) provided a detailed view of the anticyclonic cirrus outflow and a partial view of the underlying cumulonimbus. The cumulonimbus appeared to be alined with the loosely organized vortex of a forming tropical storm.

No trace of a storm could be found on June 20 by Air Force reconnaissance; nor could remains of what had been called Dolores be found even in the satellite pictures. It seems likely that there would have been some evidence of spirally organized clouds if a circulation of tropical storm intensity had been present the day before. Therefore, for statistical purposes, Dolores should be treated as a depression.

TROPICAL STORM EILEEN

Eileen was the first storm of the season to move onto land. The storm was weak and small; damage directly attributable to its winds probably was minor. Formation of the storm was related to a large-scale Southern Hemisphere flow activating the ITCZ (intertropical convergence zone). A depression formed about 100 n.mi. south of Acapulco, Mexico, early on June 26; winds at Acapulco were easterly at 20 to 25 kt. When considering the winds at Acapulco, APT photographs could have been interpreted as indicating the existence of a minimum-intensity tropical storm.

The center moved west-northwest parallel to the coast for 24 hr at a speed of about 5 kt. It then started accelerating on a broadly recurving path that barely cleared Cape Corrientes, between Manzanillo and Puerto Vallarta, at about 1800 GMT on June 28. Ships had reported winds of 35 kt with rough seas between the storm center and the coast from 1800 GMT on June 27. The recurving path took the weak storm inland 30 or 40 n.mi. southeast of Mazatlán shortly before midnight (local time) on June 28. Mazatlán Airport winds changed from southwest at 10 kt to east-northeast at 15 kt during the 2-hr period as the storm was approaching the coast. Satellite pictures of heavy cloud masses suggested that the flow of warm, moist air associated with the generation of Eileen caused heavy rains extending from the coast inland to the mountains between Acapulco and Mazatlán.

HURRICANE FRANCESCA

The first indication of the disturbance that became hurricane Francesca was seen near 9°N, 87°W, on an ESSA 8 picture taken at 1533 GMT on July 1. A developing tropical storm could be seen near 10.6°N, 90.3°W, in the ESSA 8 picture on the following day; a negligible amount of detail was visible because of the profuse cirrus outflow. Further intensification was evident on the ITOS 1 picture taken a few hours later.

A violent hurricane at 11.0°N, 95.2°W, was reported by the *Adabelle Lykes* at 1800 GMT on July 3. The ship estimated 85-kt easterly winds and 45-ft wave heights. The barometer read 1002 mb and had fallen 5.5 mb during the preceding 3 hr. The ship, 3 hr earlier, had been moving southeast at 18 kt with winds of only 30 kt. Satellite

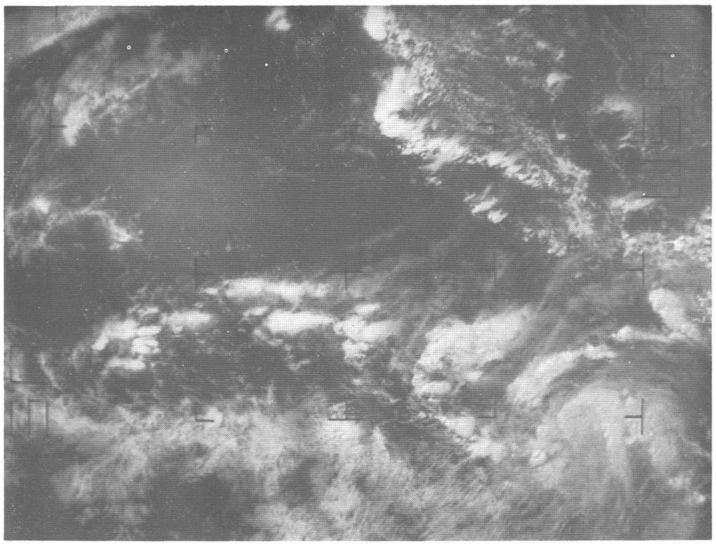

FIGURE 4.—ITOS 1 view, orbit 2020, on July 3, 1970, depicting Francesca (a young hurricane with 85-kt winds) in the lower right corner.

pictures (see fig. 4) showed the hurricane eye hidden under the cirrus cap and indicated that storm winds were limited to a small area.

The first reconnaissance into the hurricane was by the Air Force at 1800 GMT on July 4; this was the most distant reconnaissance fix (11.8°N, 101.3°W) of the season. Maximum winds of 70 kt were indicated by the sea surface 25 n.mi. from the center in the northern semicircle, with much lighter winds in the southern semicircle. A minimum pressure of 991 mb was measured by dropsonde. The hurricane was open above 18,000 ft except for a cirro-stratus cap (27,000-ft base and 40,000-ft top). The cap was penetrated by towering wall clouds on the northeast side of the eye. The eye was elliptical, 15–20 n.mi. in diameter. Satellite pictures on July 4 did not show the usual tightly coiled hurricane appearance because of the heavy cirrus cap over the eye and inner bands.

The cirrus cap had begun to move off the lower clouds around the storm center when the ESSA 8 picture was taken at 1703 GMT on July 5. The southwest half of the eye was visible in an ITOS 1 photograph at 2200 GMT. This shifting of the cirrus cap from the eye ordinarily is indicative of a reduction in volume of air rising up the eye-wall chimney and therefore of decreased inflow and a weakening storm (Denney 1969). The center of the storm was fixed by Air Force reconnaissance at 1800 GMT, but maximum winds could not be estimated from the sea surface because of "extensive cloud cover in and around the storm center." Reconnaissance reported further that the center was circular (30 n.mi. in diameter) and poorly defined; thus it was difficult to locate among increasing cumulonimbus in the surrounding area.

Reconnaissance by the Air Force on July 6 found Francesca weakened to a tropical storm with 45-kt maximum winds. The stongest winds were observed 20 n.mi. east of the center. The center was poorly defined and circular, with a diameter of 35 n.mi. A partial wall cloud remained in the east and west quadrants, and there was extensive cumulus and cumulonimbus activity to the east and south. A cirrostratus cap covered the entire storm with blowoff to the northeast, presumably from the existing, partial eye-wall chimney. ITOS 1 APT photographs a few hours later showed the western half of the remaining eye-wall clouds visible through the cirrostratus.

Navy reconnaissance penetrated the weakening storm at 1735 GMT on July 7 at 600 ft, finding maximum surface winds of 35 kt and a minimum sea-level pressure of 1006 mb. The strongest winds were about 30 n.mi. northeast of the center and were associated with squalls. No eye could be seen on radar, and no wall clouds were observed.

Sea-surface temperature under the storm was measured by Navy reconnaissance on July 7 at 83°F, a temperature sufficiently high to sustain a hurricane if other necessary conditions prevail. Satellite pictures and the surface map gave no indication of the onset of cool air inflow or reduction of inflow; dissipation probably was due to loss of the necessary high-level divergence. Such loss could have come about through proximity of the storm to a weak high-level jet stream around the cold Low centered about 800 n.mi. northwest of Francesca on July 5.

A final reconnaissance into the dissipating storm was made by the Navy on July 8; there were 30-kt maximum winds. Winds as strong as 25 kt were limited to the northeast quadrant within 50 n.mi. of the center. The remnants of the cloud eye were poorly defined.

TROPICAL STORM GRETCHEN

Gretchen was a minor tropical storm with maximum winds of about 45 kt from July 14, the date it was discovered by ESSA 8 photography, through July 16. Gretchen maintained minimum tropical storm intensity, with 35-kt winds, on July 17 and 18.

Air Force reconnaissance obtained position fixes (see fig. 1) and intensity estimates on July 15 and 17. Navy reconnaissance covered the storm on July 16. Dissipation of the residual depression was watched by satellite through July 21.

Changes in direction of movement and speed of the storm, which occurred at about the time reconnaissance obtained position fixes on July 15 and 16, contributed to large errors in position forecasts of intermediate advisories.

TROPICAL STORM HELGA

The beginnings of Helga were discovered about 130 n.mi. south of Manzanillo, Mexico, in a Nimbus picture taken at 1800 GMT on July 16. Air Force reconnaissance found a minimum-intensity tropical storm at 1952 GMT on July 17, with maximum winds of only 35 kt. Interpretation of the ESSA 8 picture, taken at 1640 GMT on July 18, indicated intensification as the storm moved toward southern Baja California from less than 200 n.mi. to the southeast. If it was intensifying at the time, the trend promptly reversed. An ITOS 1 picture taken 6 hr later revealed that the cirrus shield that earlier had spread over southern Baja California was dissipating. Apparently, the divergence aloft, needed to maintain outflow from the storm, had been lost. Helga dissipated on July 19 and 20 while stalled less than 100 n.mi. south of the tip of Baja California.

TWO TROPICAL STORMS CALLED IONE

Post season analysis indicates that the two tropical cyclone centers called Ione must be considered as separate and discrete storms, even though they apparently shared the same high-level outflow system and originated in the same large area of squalls.

The first evidence of cyclogenesis came at 0600 GMT on July 22 from the ship *Castilla* located 25 n.mi. southeast of Acapulco. Lightning was visible from the ship, the winds were east-northeast at 30 kt, and the barometer read 1011 mb and holding steady as the ship moved southeast at 20 kt. Twelve hours later, a ship report from 200 n.mi. south-southwest of Acapulco told of 30-kt southwest winds and a barometer reading of 1001.5 mb and rising 5.7 mb in 3 hr (with a check tendency) as the ship moved southeast at 20 kt. This suggested that a tropical storm had just been traversed, if pressure data were accepted as reported—it was assumed that wind directions were from the south or south-southwest. The operational bulletin issued at that time (1800 GMT) was based on the conclusion that the ship had gone through a thundersquall and that the pressure reading received was probably in error by 9 mb because of transposition of figures in relay.

A picture from ITOS 1 at 2238 GMT on July 22 suggested the existence of an intensifying tropical depression, with its center somewhere near the position indicated by the later ship report. The picture revealed extensive cirrus outflow from an area 300 n.mi. across. The outflow appeared to have one anticyclonic source 260 n.mi. southwest of Acapulco and a second source about 200 n.mi. west-northwest of the first. The second cirrus outflow was manifested by noncurving radial plumes.

The extensive cirrus outflow disappeared before the satellite pictures were taken on July 23. A circulation center was barely apparent near 15.0°N, 106.5°W, in the ESSA 8 picture; low-level banding, which had been exposed to view from above by dissipation of the cirrus, was quite limited. The picture supported no more than weak depression intensity, and its lack of spiraled convective bands told that circulation had been slight the previous day.

The few ship reports received during the night of July 23–24 seemed to indicate the presence of a disturbance, about 150 n.mi. off the mainland, moving northwest toward Baja California. Pictures from ESSA 8 on July 24 had the east part of the area of concern on orbit 7356 and the west part on 7357. A picture taken at 1756 GMT during the latter orbit showed a dense, nearly circular cirrus mass with lower level thin feeder bands around the periphery entering the storm at a steep angle. The mass was about 4° latitude in diameter; orientation of the external bands suggested that the center of activity was near 16°N, 110°W. Pictures from orbit 7356 had shown general shower activity east and northeast from the round cirrus mass to the coast of Mexico, including large irregular patches of cirrus which could have hidden a circulation center. Numerous open convective cells, such as those seen in middle or northern latitudes with unstable cyclonic flow, could be seen where the cirrostratus had not spread out in a continuous sheet.

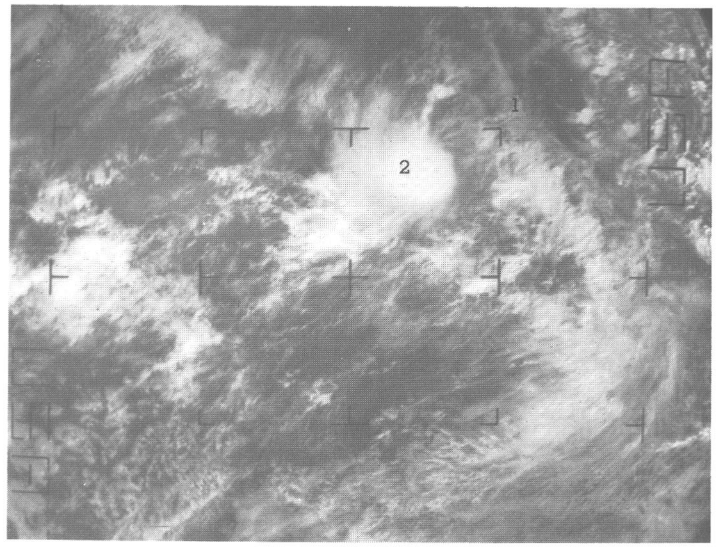

FIGURE 5.—ITOS 1 picture, orbit 2283, on July 24, 1970, showing Ione 2 (a vigorous young storm) and Ione 1 (which had 48-kt winds 300 n.mi. to the northeast 1.5 hr earlier).

At 1800 GMT, Socorro Island, on the north edge of the circular cloud mass, reported northerly winds at 5 kt and a pressure at 1012.4 mb and rising about the normal diurnal rate. That report, together with reports from ships to the east (and within 150 n.mi. of the coast of Mexico) showing pressures near 1010 mb, southeast winds 25–30 kt, and rough seas, placed a low-pressure center about 130 n.mi. west-southwest of Puerto Vallarta. At 2100 GMT, the *Kamikawa Maru*, 100 n.mi. west of Puerto Vallarta, encountered 48-kt southeast winds and 15-ft seas; the barometer was reading a steady 1011.0 mb as the ship moved southeast at 15 kt. A tropical storm apparently was centered 20 to 30 n.mi. west of the ship. That storm is indicated as Ione 1 on figure 1. The ITOS 1 picture (fig. 5) taken 1 hr and 35 min after the ship report, and showing detail much better than ESSA 8, did not support the diagnosis of a conventional tropical storm at picture time. It did show an open convective cell 40–50 n.mi. in outside diameter, in approximately the correct position, with a line of cumulonimbus—suggesting a small spiral, extending about 75 n.mi. to the southwest; but there was no cirrus outflow. There may have been cirrus outflow earlier, considering that the storm was dissipating rapidly when photographed.

The really striking feature of the ITOS 1 picture shown in figure 5 was the classical young tropical storm, Ione 2, capped by a round disc of cirrus 2.5° in diameter. The storm was centered near 16.4°N, 110.8°W, about 300 n.mi. southwest of Ione 1. There was sharply curved anticyclonic outflow to the west and northwest. A line of large cumulonimbus rotating around the north side of the storm gave the impression of a low-level band 125 n.mi. long entering the white cloud disc perpendicularly, but the less prominent external banding conformed to a tightening spiral. The large cumulonimbus at the north end of this line had what appeared to be small spiral bands around its northeast side. This formation led to speculation as to whether it might be a "subsynoptic," mini-storm of the kind reported by Baum (1970), with dimensions similar to those of a tornado cyclone.

Navy reconnaissance of Ione 2 at 1800 GMT on July 25 found maximum winds of 45 kt around a poorly defined center open to the south. The ESSA 8 picture taken about an hour earlier showed the weakened storm as a spiral of narrow, low and middle cloud bands; the cirrus cap, which had obscured inner banding the day before, had drifted off to the west and nearly dissipated. Water temperature under the storm was 80°F, but cool surface inflow from the north was entering the central area. Dissipation continued, and most of the remaining clouds within 25 n.mi. of the center dissipated during the following 24 hr. No storm activity was apparent to Air Force reconnaissance on July 26.

TROPICAL STORM JOYCE

Tropical storm Joyce developed in a broad, flat low-pressure area that persisted south of Baja California after the demise of Ione. Circulation around the periphery of the large Low increased on July 28, with winds up to 30 kt on the west side; squalls developed on the southeast side where there was convergence against the rugged terrain of Mexico.

A smaller Low circulation with its center about 120 n.mi. south of Manzanillo formed early on July 29. Tropical storm Joyce, centered at 17.5°N, 106.0°W, was named at 1800 GMT, after the ship *Mangocore* reported 35 kt east-southeast winds a few miles to the northeast. A 1628 GMT ESSA 8 picture showed a nearly circular disc of dense cirrus about 1.5° of latitude in diameter; anticyclonically curved plumes extended to the southwest and northwest. The center of the lower level cloud spiral was not clear.

U.S. Navy reconnaissance on July 31 found 45-kt maximum winds at 0118 GMT and 50-kt winds at 1800 GMT; the radius of 30-kt winds was only 30 n.mi. Satellite pictures on July 30 again showed a nearly circular cap of dense cirrus about 1.5° of latitude in diameter over the storm center; the cirrus cap was still there on July 31, but it was somewhat less regular in shape.

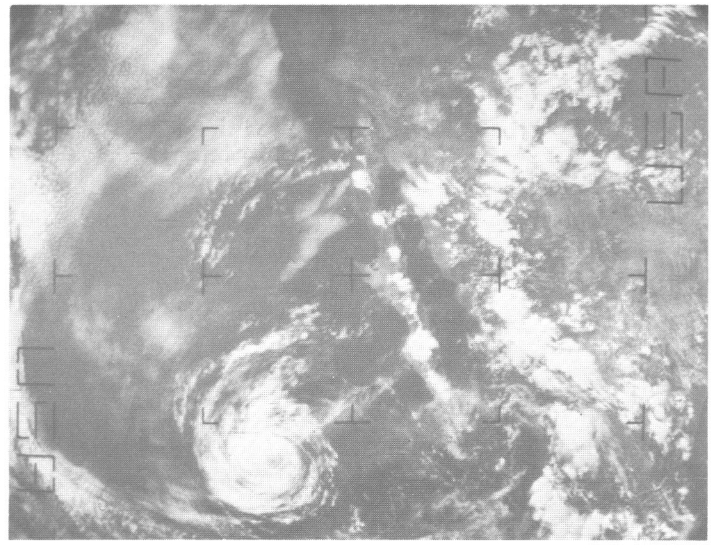

FIGURE 6.—ITOS 1 view, orbit 2383, on Aug. 1, 1970, depicting Joyce (weakened to a depression) in the left foreground.

On August 1, Air Force reconnaissance found that the storm had decreased to minor depression intensity with 30-kt maximum winds. Interpretation of satellite pictures of August 1 (fig. 6) was clarified by reconnaissance that reported wall clouds with tops only to 5000 ft around the 15-n.mi.-diameter eye, feeder bands with tops to 7,000 ft, and cirrostratus (29,000-ft base and 40,000-ft top) capping the entire system. Radar returns were negative, and there was no precipitation; reconnaissance measurements at 700 mb showed that the core temperature was still 4°C higher than the environment. Dropsonde measured a surface pressure of 1000 mb.

The cloud spiral was still clearly visible on satellite pictures through August 3 as the dissipating depression moved to the west at 7 kt. On August 2, winds stronger than 15 kt were limited to the trades on the north side. Dissipation was attributed to inflow of cold air from over cold water along the west side of Baja California; this inflow was indicated by surface streamlines as early as July 31.

TROPICAL STORM KRISTEN

Kristen was never more than a loosely organized tropical storm; it developed from a disturbance that was causing squalls near the coast of Mexico, with 20-kt easterly winds reported by Acapulco at 1800 GMT on August 4. Tropical storm intensity was indicated by a 2100 GMT August 5 ship report of 35-kt southeast winds and heavy rain about 40 n.mi. off Zihuatanejo. Close study of a 2221 GMT ITOS 1 APT photograph placed the center of the convective cloud spiral near 17°N, 104°W.

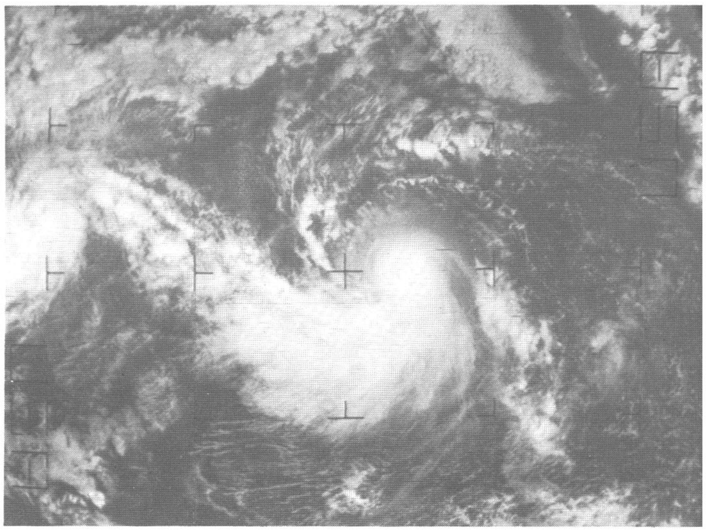

FIGURE 7.—ITOS 1 picture, orbit 2621, on Aug. 20, 1970, showing Lorraine (near the center of the picture) and Maggie (to the west along the edge of the picture).

The weak storm was tracked through August 6 by means of ship reports, most of which were on the east and northeast sides of the storm, and satellite pictures. A ship report of 40-kt winds in the mouth of the Gulf of California at 1800 GMT on August 6, another from 150 n.mi. west of Cape San Lucas at 0600 GMT on August 8, and two reconnaissance fixes (with 40-kt winds reported) by the U.S. Navy at 1553 and 2125 GMT on August 7 were key data. Reconnaissance also reported a 1000-mb pressure in the eye and a low-level temperature 2.5°C higher in the eye than in the environment. Kristin dissipated abruptly on August 8 under the influence of relatively cold water west of Baja California.

HURRICANE LORRAINE

Lorraine and Patricia were the two hurricanes of the 1970 season believed to have had maximum winds of about 100 kt. Lorraine developed slowly and reached hurricane intensity west of 115°W where most Eastern Pacific hurricanes weaken. This anomalous behavior appears to have been related to the existence of tropical storm Maggie to the west. The circulation around Maggie apparently diverted the low-level cool air, which usually flows in from the north, away from Lorraine and caused an increased inflow of moist unstable air from the ITCZ (fig. 7).

The initial low-pressure center can be traced from about 300 n.mi. southwest of Tehuantepec. It was brought to attention by an 1800 GMT July 15 ship report of 25 kt east-northeast winds, with a pressure of 1011 mb falling at the rate of 1 mb/3 hr, as the ship moved east at 15 kt. The Low then moved west for 2 days with no ship-reported winds more than 20 kt. Satellite pictures indicated little change on July 16; definite intensification was indicated on July 17 with an expanded area of rotation shown by the spiral banding. The picture on the 18th again indicated a period of little development; then for more than 3 days, there was steady intensification, documented by daily reconnaissance and twice-daily APT photographs.

U.S. Air Force reconnaissance found 35-kt maximum winds on July 18; Navy low-level reconnaissance found 50-kt winds on July 19 and reported a sea-surface temperature of 84°F with a 4°C rise in low-level air temperature on penetration of the storm eye. The *Margaret Lykes*, moving southeast at 18 kt, passed through the eye of the storm between 2000 and 2100 GMT on July 19 and still estimated 50-kt winds and 25-ft seas 3 hr later.

Hurricane intensity was reached at 1830 GMT on August 20; U.S. Air Force reconnaissance found 65-kt maximum winds and reported a minimum sea-level pressure of 988 mb (by extrapolation from the 700-mb height). Reconnaissance further reported that the eye was elliptical with a solid wall of stratiform clouds giving excellent radar return and that the 700-mb eye temperature was 15°C as compared to 13°C in the environment. Pictures on the 20th (see fig. 7) were remarkable for the apparent heavy cirrus production, with anticyclonic outflow to the southwest from the top of the eye-wall chimney and a broad feeder band from the direction of developing tropical storm Maggie to the west.

U.S. Air Force reconnaissance into the hurricane at 1720 GMT on August 21 reported the sea-level pressure down to 978 mb (again by extrapolation from the 700-mb height) but could not observe surface winds because of solid clouds obscuring the sea. The aircraft broke into the clear upon entering the eye at 300 mb, but the eye was still capped by a higher level cirrostratus deck at that time. An unbroken wall cloud, well defined by radar, extended upward to the cirrostratus. Satellite pictures on the 21st depicted an intensifying and expanding hurricane. The cirrostratus over the eye appeared translucent with the eye faintly visible in the ESSA 8 photograph. Multiple heavy feeder bands spiraled in from the south and southwest.

Air Force reconnaissance at 300 mb at 1730 GMT on August 22 reported a temperature of −21°C in the 17-n.mi. diameter eye, some 10° higher than that of the environment. The computed minimum sea-level pressure was 963 mb. The reconnaissance meteorologist reported: "The hurricane radar returns were almost classic with a center completely circular." Maximum surface winds were not observed due to solid clouds around the eye.

Pictures on the 22d were of a mature hurricane with maximum winds near 100 kt (fig. 8). The perfectly round eye seen by reconnaissance was clearly visible, and internal banding was defined by bulges in the solid cloud top, which cast shadows on the northeast side. However, the feeder bands that had been on the south and southwest side the day before were losing connection to the ITCZ. There was reason to believe that dynamic processes in the storm were retaining only some of the inflow energy

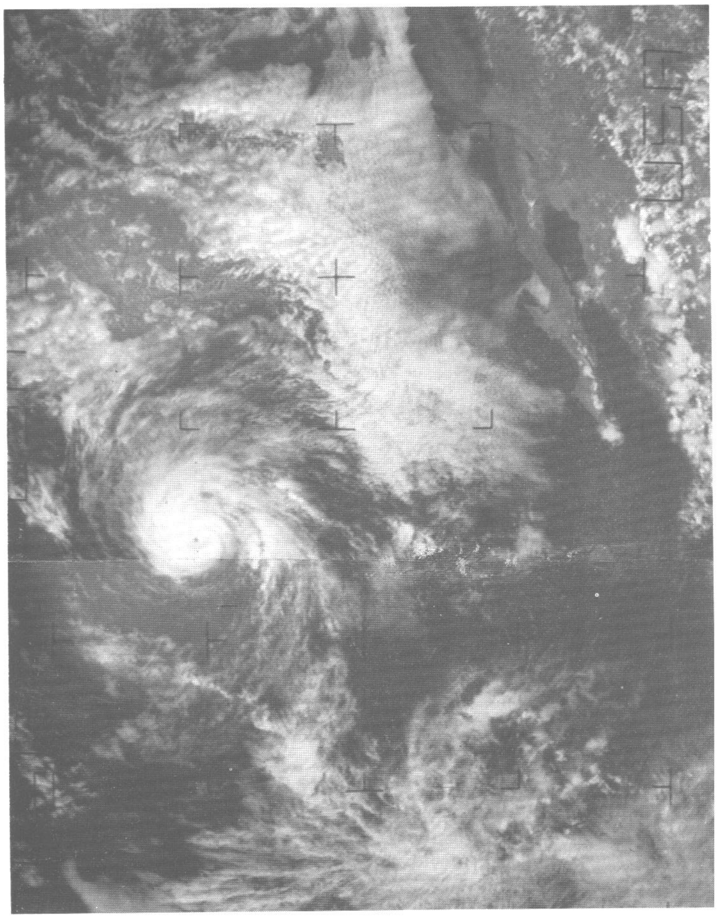

FIGURE 8.—ITOS 1 mosaic, orbit 2646, on Aug. 22, 1970, depicting Lorraine as a mature hurricane.

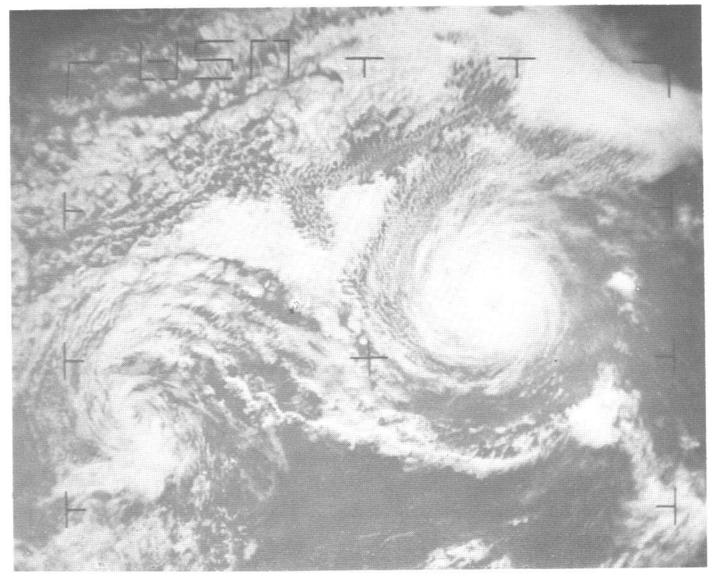

FIGURE 9.—ESSA 8 view, orbit 7734, on Aug. 23, 1970, showing Lorraine (weakened to a 60-kt tropical storm) to the right of the center fiducial point and Maggie toward the west-southwest.

for release in the eye wall, but were releasing most of it about 200 n.mi. east of the center where cumulonimbus were more numerous and developed than downstream along the spiral toward the hurricane. Premature release of inflow energy would mean less heat would be released in the eye-wall chimney and the concentration of warm air and pressure gradients would be reduced near the eye. In the satellite pictures, it was seen that the continous stratocumulus sheet northeast of the storm area was disturbed by the storm circulation; it could be assumed that cold surface air was flowing in with the usual cross-isobaric component toward lower pressure.

Weakening was well underway when Air Force reconnaissance made a detailed eye report at 1730 GMT on August 23. Cloudiness had decreased, permitting an observation of 60-kt maximum surface winds 30 n.mi. north-northwest of the center; wall clouds were no longer solid to the south and southwest. At 300 mb, the eye temperature was then only 6°C higher than the environment. Radar showed the structure was still well defined. A clear ESSA 8 picture (fig. 9) showed an extensive stratocumulus deck, apparently formed by breaking of stratus around the north and northwest periphery, wrapped around the west side of the storm within 200 n.mi. of the center. This indicated the inflow of stable air. Feeder bands in the south semicircle were completely gone, and a nearly clear tongue of air about 100 n.mi. wide separated the storm from warmer water to the south and southeast. Fringes of the hurricane cloud spiral were feathered as if dissipating, and the dimly visible eye had become irregular in appearance as could be expected with the deterioration of the eye wall reported by reconnaissance.

The decrease in storm intensity continued. Air Force reconnaissance on August 24 reported 50-kt maximum winds about 15 n.mi. south of the center and reported a computed minimum pressure of 994 mb. Wall clouds were still solid from northeast to northwest, and the −29°C 300-mb eye temperature was 4° higher than the environment. Satellite pictures were noteworthy, mainly for showing that the decreasing storm cloud mass was overrunning a sheet of stable stratocumulus to its northwest. This stratocumulus was assumed to be associated with continuing cool inflow.

Dissipation could be observed only by means of the satellite pictures of August 25; all available reconnaissance facilities were concentrating on tropical storm Maggie threatening Hawaii. The pictures suggested a baroclinic interaction between low-level stable air around the storm center and renewed inflow from the southeast. Heavy convective cloud masses formed 150–300 n.mi. east of the storm center, where there was no contribution of warm air to the storm core.

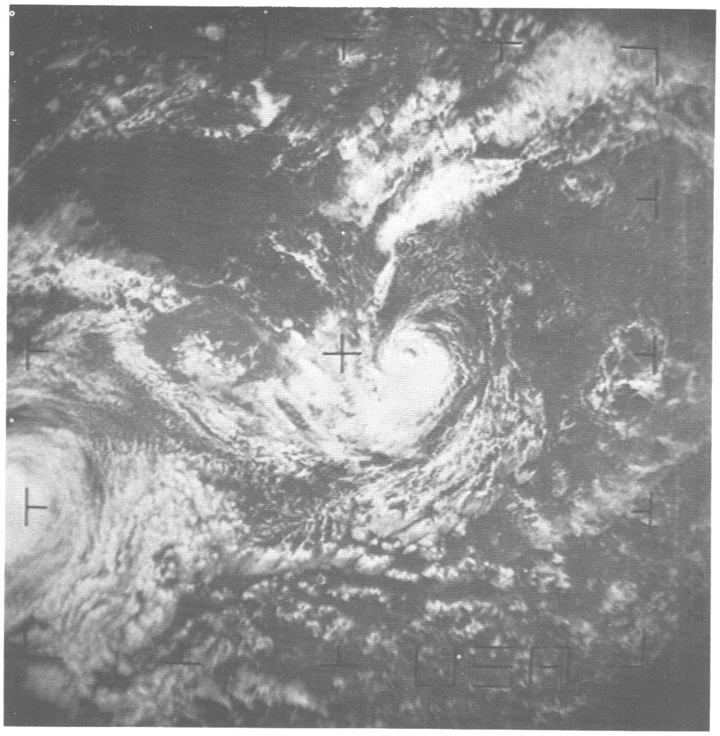

FIGURE 10.—ESSA 8 picture, orbit 7747, on Aug. 24, 1970, depicting Maggie near the center of the photograph. On the next day, this storm produced 10–15 in. of rainfall on the windward side of the island of Hawaii.

Reconnaissance by the Air Force at 1830 GMT, on August 26 reported the center at 20°N, 140°W, to be well-defined in the broken cloud pattern and a 300-mb eye temperature of −34°C, the same as in the environment. The remarks concluding the detailed eye report effectively described the end of Lorraine: "Northwest quad overcast, top 3000, scattered altostratus tops 10,000; remainder of area tops 3000; well-defined bands. Negative cirrus; negative buildups; negative winds at 19°50′N, 139°30′W." The remaining weak circulation could be followed for only about 24 hr.

TROPICAL STORM MAGGIE

Maggie was a significant storm for having caused very heavy rains and for having threatened strong winds on the island of Hawaii. The cloud vortex that eventually developed into Maggie was discernible on satellite pictures as early as August 17. It was then near 13°N, 116°W, as Lorraine was intensifying to tropical storm intensity 650 n.mi. to the east. The slowly organizing vortex, after moving west-southwest for 2 days, reached a clearly intensifying state while moving west-northwest on August 20 (fig. 7). The ship *Biafra* reported 38 kt southerly winds 50 n.mi. southeast of the new storm center at 0000 GMT on August 21. Maggie had been moving faster than Lorraine, thus increasing the distance between the storms to 850 n.mi.

Air Force reconnaissance at 2008 GMT on August 21 found it necessary to descend through solid clouds from 300 to 850 mb to fix the storm center, using pressure, temperature, and wind measurements, since radar depiction revealed no organized activity. Maximum surface winds of 40 kt were found 45 n.mi. west of the center; the poorly defined eye was circular (25 n.mi. in diameter), with large breaks on the northeast and west and large feeder bands entering from the southwest. Scattered cumulonimbus had tops to 35,000 ft, and cirrostratus covering the entire area had tops above 35,000. A sea-level pressure of 999 mb in the eye was extrapolated from the 850-mb height. Pictures contributed slightly on August 21, but they did raise a question as to possible stable inflow from the trade-wind belt to the north.

At 1800 GMT on August 22, Air Force reconnaissance fixed the center at 14°55′N, 138°42′W, and reported maximum winds of 50 kt. The poorly defined eye was open from north through southwest; and at 700 mb, the eye temperature (13°C) was 4° higher than the environment. "An abnormal amount of moderate to heavy rain was encountered upon entering from the east, but the radar echo had only slight curvature." Pictures on the 22d showed a faintly visible eye. The central overcast, about 2° of latitude in diameter, was an almost perfect semicircle along its northwest periphery. The stratocumulus sheet around the north side of the storm was breaking up, as if there were widespread low-level convergence lifting the trade inversion.

On August 23, Air Force reconnaissance circumnavigating the storm area at 300 mb found neither cloud pattern nor center by radar. The satellite pictures still showed prominent spiral structure in the cloud pattern centered near 15°N, 142°W (fig. 9), with layered clouds near the center apparently dissipating and numerous scattered cumulonimbus in a 100- to 150-n.mi.-wide feeder band extending from 250 n.mi. southwest to 75 n.mi. east-southeast of the storm center.

Maggie was fixed at 17°53′N, 148°47′W, by U.S. Air Force reconnaissance visual inspection of the cloud pattern from a 300-mb flight level at 2148 GMT on August 24. A solid wall of clouds with infrequent lightning extended for 100 n.mi. from the north to the southeast; tops were 40,000 ft, and cirrus was blowing off to the east. The 15-n.mi.-diameter circular center was filled with multilayered clouds to 16,000 ft. Maximum winds of 25 kt were estimated through breaks in the undercast about 20 n.mi. out in the south semicircle. Dropsonde eye surface pressure was 1003 mb. At 1930 GMT, ESSA 8 pictures (see fig. 10) showed a dark shadow lying northwest to southeast across the center of the storm. This shadow was cast by the wall of cloud seen by reconnaissance 2 hr later. The picture also showed a feeder band (30 to 50 n.mi. wide) apparently containing numerous cumulonimbus from about 200 n.mi. south to 75 n.mi. northeast of the center.

Maggie had weakened on August 25 when studied by Air Force multilevel reconnaissance less than 250 n.mi. east-southeast of Hilo. Tops of cumulus were generally about 28,000 ft, and the center had a weak wall cloud only in the east quadrant. Maximum observed surface winds were 25 kt 25 n.mi. from the center on the southeast side. The temperature at 500 mb in the center was −5°C; the environment temperature was −7°C.

Maggie passed 80 n.mi. south of Hawaii later on August 25, dumping a total of 10–15 in. of rain on the windward side (from the Hamuka coast to Puna) and 1–7 in. on the leeward side. It then moved west as a slowly weakening depression.

TROPICAL STORM NORMA

Norma was one of the more notable storms of the 1970 season, but not because of her intensity. The circulation around this storm forced into Arizona the moist, unstable tropical maritime air mass that was the primary cause of the disastrous floods of September 4–6 (fig. 11). Over Arizona, the unstable air mass met a slowly moving cold front; the northward-moving air mass entered a zone of rapid convergence ahead of the front and at the same time was forced upward against rugged terrain. The resulting heavy orographic precipitation caused the floods.

The storm first appeared on an ESSA 8 picture taken on August 30; a related weak low-pressure center appeared about 100 n.mi. southwest of Acapulco. Rapid intensification to a tropical storm led to ship reports of winds up to 45 kt by 2000 GMT on the next day. The storm was loosely organized about 250 n.mi. south of the tip of Baja California when investigated by Air Force reconnaissance on September 1. In the ITOS picture, the cirrus outflow appeared greater from the tops of feeder bands than from the eye-wall chimney.

The storm circulation was more organized when Navy low-level reconnaissance found 50-kt maximum winds 20 n.mi. southwest of the center at 1830 GMT on September 2. The temperature in the eye (27.2°C) was 3.8° higher than in the environment.

Dissipation began while Navy low-level reconnaissance studied the storm on September 3. Maximum winds were 50 kt at a point 20 n.mi. east-southeast of the center at the 1645 GMT first fix, but were only 35 kt at 2045 GMT. Reconnaissance Officer Warner summarized: "During second fix penetrated 500 ft and observed drastic change in radar presentation and enlargement of center to 50 n.mi. Negative wall cloud, rain or turbulance; minimum surface pressure 994 mb; maximum temperature 23.8°C with only 0.4° difference." On the first fix, there was an apparent wall cloud 5 n.mi. thick in the west semicircle; the eye was 1.2°C higher than the environment; and minimum pressure was 992 mb. Satellite pictures suggested the presence of a cool inflow with a continuous sheet of stratocumulus around the west semicircle extending under the storm clouds about 200 n.mi. from the center.

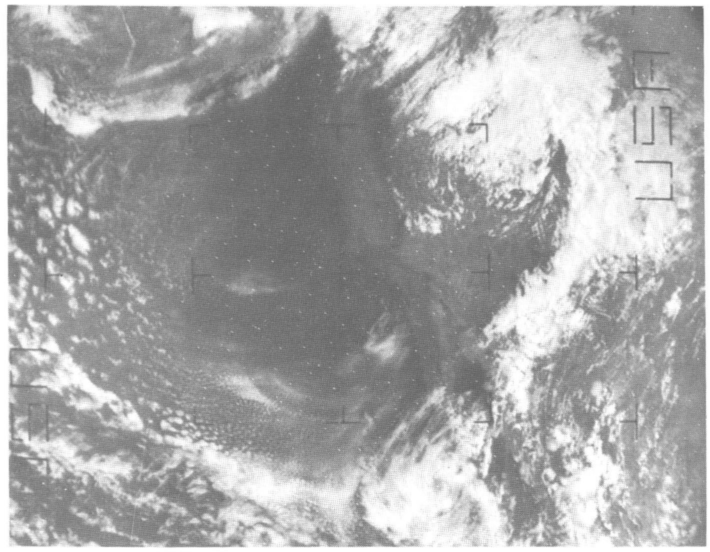

FIGURE 11.—ITOS 1 view, orbit 2821, on Sept. 5, 1970, showing Norma (weakened to a depression off Baja California) near the center foreground. In Arizona, a deluge of frontal orographic rain occurred.

Norma was only a depression west of southern Baja California when investigated by Navy reconnaissance and photographed by satellite on September 4; by then, flood rains were falling in Arizona. A cloud spiral was still visible west of Baja California on the satellite photographs of September 5 (fig. 11), but there no longer was any surface circulation.

TROPICAL STORM ORLENE

Orlene was a problem storm for forecasters because of her unexpected movement toward the east-northeast. A strong 700-mb High north of the storm and climatology indicated westward movement. ITOS 1 pictures at 2147 GMT on September 6 showed a circulation center with cirrus outflow and spiral bands about 250 n.mi. southwest of Salina Cruz. Ships passing through the area early the next day reported swells up to 8 ft coming from northeast of the earlier location of the vortex. Then at 2100 GMT, the *Epimelia*, at 14°23′N, 95°37′W, reported: "Observed tropical storm with northeast winds force 8/9 995 mb very rough sea." A close study of the ESSA picture taken 5 hr earlier led to the tentative identification of a round cloud mass with a 40-n.mi. diameter as the storm embedded in a much larger and more or less amorphous mass. If identification was correct, the storm had moved west during the 5-hr period; when considering later events, this identification was probably erroneous.

Air Force reconnaissance and satellite pictures on September 8 found nothing west of the earlier location of Orlene that could be related to a dissipating tropical storm. The pictures did show a rather weak circulation and cloud spiral over the Isthmus of Tehuantepec, north-

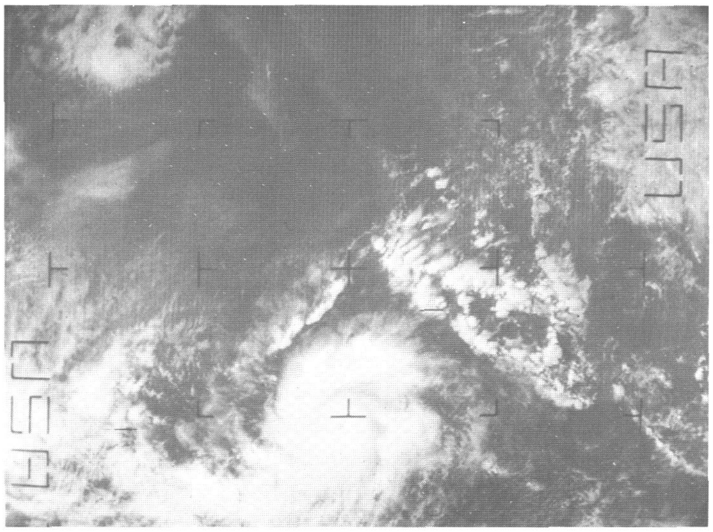

FIGURE 12.—ITOS 1 photograph, orbit 3196, on Oct. 5, 1970, depicting Patricia (a young and rapidly intensifying hurricane) in the foreground.

east of Salina Cruz. It was concluded that the 700-mb analysis showing a High north of the storm on September 7 was based on inadequate data and that more extensive data would have revealed a shear line south of the High center with the storm environment moving toward the east-northeast.

HURRICANE PATRICIA

Patricia was the second hurricane of the season to have maximum winds near 100 kt. Patricia (of concern to mariners only) followed a west-northwest path away from Mexico as did the other three hurricanes.

Development in the ITCZ south of Tehuantepec was noticeable in the form of increasing convection as early as October 2. Anticyclonic cirrus outflow and the organization of a low-pressure circulation at the surface were evident in satellite pictures and ship reports on October 3. Satellite pictures on the 4th revealed an intensifying tropical storm. The ITOS 1 picture of 2210 GMT on October 5 (fig. 12) disclosed a perfectly round eye, barely large enough to be resolved by the camera system, under an abundant anticyclonic outflow of dense cirrus through which tightening bands of cumulonimbus were visible.

Air Force reconnaissance at 1829 GMT on October 6 reported a hurricane with 90-kt winds and a minimum pressure of 979 mb at 14°30′N, 109°55′W. The temperature at 700 mb was 15°C in the eye and 10° outside the eye. Winds as strong as 85 kt were measured at the 700-mb flight level. The eye was circular (15 n.mi. in diameter); and radar presentation was excellent. To ITOS 1, a small eye was faintly visible.

Navy reconnaissance went into hurricane Patricia at 15°52′N, 115°48′W, at 1825 GMT on October 7 and found maximum winds still at 90 kt and minimum sea-level pressure at 976 mb. Temperatures at the 700-mb flight level were 22.8°C in the eye and 14.0°C outside the eye; the closed wall cloud averaged 12 n.mi. in thickness, causing moderate turbulence and heavy rain upon penetration; the maximum winds were observed along the inner edge of the wall clouds, and the radius of the 50-kt winds was 30 n.mi. Sea-surface temperature was 81.6°F, and there was moderate to heavy feeder band activity 90 n.mi. east and south of the small eye. Satellite pictures compared well with the reconnaissance report and showed what appeared to be a stratus sheet, undisturbed by the storm circulation in stable air about 400 n.mi. northwest of the hurricane.

The Air Force hurricane reconnaissance on October 8 found Patricia centered at 16°30′N, 120°46′W, at 1750 GMT with 95-kt maximum surface winds and a 972-mb minimum pressure. Hurricane presentation on radar was still excellent, and feeder bands were well defined; but the eye wall was open to the north. The strongest winds were located 20 n.mi. northwest of the center. The eye temperature at 700 mb was down to 17°C. Pictures from ESSA 8 on the 8th revealed that the stratus that had been to the northwest on the 7th was breaking to stratocumulus and was wrapped around the west semicircle of the storm to within 150 n.mi. of the center. Feeder bands on the south and southeast were losing connection to the ITCZ. ITOS 1 pictures showed that most of the stratocumulus seen earlier on ESSA 8 pictures had dissipated. The dissipation is attributed to vertical stretching of the layer below the inversion until the inversion had broken, with downward mixing of relatively dry air from above. An eye was faintly visible, but it was irregular in shape; feeder bands from the ITCZ had broken completely.

Patricia was slow to weaken after the feeder bands to the south and southeast broke; short bands still embedded in the hurricane circulation rotated to the north semicircle. At 1745 GMT on October 9, Navy reconnaissance penetrated the northeast quadrant of the hurricane at 500 ft. The center was at 17°25′N, 125°05′W, and maximum winds were 95 kt with gusts exceeding 100 kt; there was moderate to severe turbulence. A 2.1°C temperature rise (to 25.1°C) occurred upon entering the eye, and the minimum sea-level pressure was 980 mb. Visible on the radar presentation were a closed wall cloud 10 n.mi. thick, surrounding the 18-n.mi.-diameter circular eye, and feeder bands out 30 n.mi. in the west quadrant. "Extremely high seas" were observed to 20 n.mi. from the center, and the radius of 50-kt winds was 45 n.mi. The sea-surface temperature was 76°F. Pictures from ESSA 8 (see fig. 13) taken less than an hour after the reconnaissance did show the tightly coiled feeder bands in the west quadrant that had been seen on reconnaissance radar; but the center of the hurricane, including the eye, was covered by cirrostratus. A few, thin feeder bands were again evident to the east and southeast of the

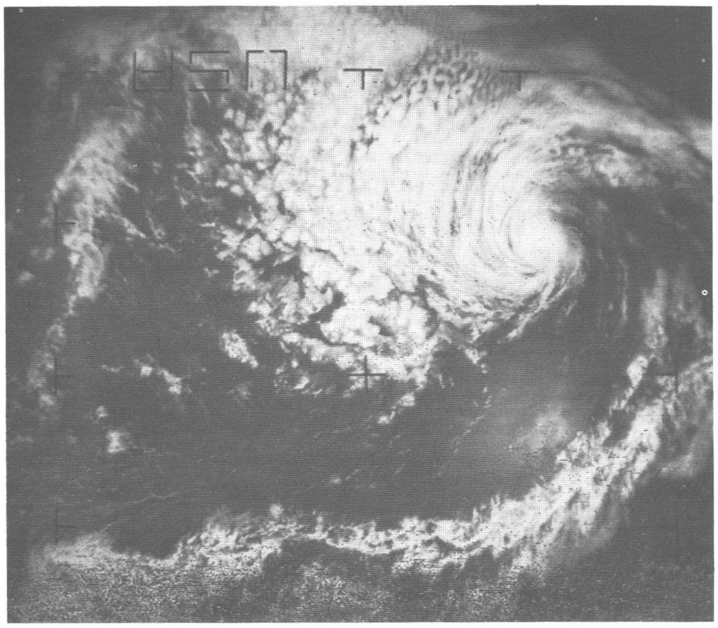

FIGURE 13.—ESSA 8 picture, orbit 8324, on Oct. 9, 1970, showing Patricia (still a 95-kt hurricane that weakened rapidly during the next 24 hr).

hurricane. Application of Timchalk's system (Anderson et al. 1969) gave an estimate of a considerably lower wind speed than was observed in the storm.

Six hours later, Air Force reconnaissance on a "Lark Fan" track[1] made a radar fix of Patricia at 18°45′N, 125°45′W (accurate to within 20 n.mi.), and found the eye (15 n.mi. in diameter) still well formed. The position revealed that the storm had turned temporarily to the northwest (fig. 1).

The hurricane then turned west and weakened rapidly. Navy low-level reconnaissance the next day reported maximum winds of only 40 kt and a minimum sea-level pressure of 999 mb. The eye-wall clouds were gone; but on penetration of the storm center, the temperature rose 1.8°C to 23.8°. The 40-kt winds were found only 15 n.mi. from the center, inconsistent with the usual migration of the wind maximum away from the center with storm dissipation (Colón 1963). Comparison of the satellite pictures of the 10th and the preceding day showed changes in cloud pattern fully consistent with the storm deterioration found by reconnaissance. The trend continued; ESSA 8 pictures taken on October 11 were the basis for estimating maximum winds of 25 kt and for operationally treating the residual depression as dissipated.

TROPICAL STORM ROSALIE

The existence of Rosalie was confirmed by the 1300 GMT October 21 observation from the MV *Ilena*, reporting from 15°20′N, 115°00′W. The ship reported pressure dropping 6 mb to the current 1007-mb pressure, winds increasing to 40 kt from the east, seas increasing to 15–18 ft, and heavy rain beginning. A recheck of the ITOS 1 APT photograph of the preceding afternoon showed a depression or weak storm centered near 13°N, 113°W. A small ring of cumulonimbus, about 25 n.mi. in outside diameter, had semicircular arcs of cumulonimbus to its west, the nearest 40 to 60 n.mi. from the center and the other about 100 n.mi. out. The field of divergence at the top of the cumulonimbus apparently was not favorable for cirrus outflow. Except from a point about 75 n.mi. south of the center, thick cirrostratus anvils had spread over an area 50 n.mi. across; and translucent clouds had spread up to 100 n.mi. out. Outflow was apparent from cumulonimbus clusters embedded in the ITCZ, which extended for about 200 n.mi. south and southwest from the small cyclone.

Navy reconnaissance at 1830 GMT on October 22 reported 30-kt maximum winds, 1006-mb minimum sea-level pressure, a center open to the south through the southwest, heavy cumulonimbus in the northeast quadrant, a middle and high cloud shield extending northeast from the center, and a well-defined circulation.

Slight regeneration apparently occurred after the reconnaissance. The *Hoegh Musketeer*, passing through the center on the morning of October 23, encountered winds to force 8 and a sudden pressure drop to 1008.5 mb just before winds changed from northeast to southeast. Satellite pictures later on the 23d revealed the storm had undergone rapid dissipation.

TROPICAL STORM SELMA

Selma was discovered in satellite pictures of November 1 as an organizing system about 500 n.mi. south of the tip of Baja California. Abundant cirrus outflow from several arc-shaped cumulonimbus clusters was visible on the ESSA 8 picture taken at 1710 GMT. An ITOS 1 picture taken about 5 hr later showed that cirrus outflow had increased, the cloud clusters had assumed the shape of a huge inverted comma with the tail pointing northeast, and heavy feeder bands extended northeast to the comma tail from the ITCZ located just south of the comma head.

At 1830 GMT on November 2, Air Force reconnaissance found the new storm centered at 15°N, 111°W, with 35-kt maximum winds and a 997-mb minimum pressure. Temperatures at the 960-mb flight level were 21°C in the eye and 2°C lower in the environment. The eye was poorly defined; radar could not be used for fixing. The radius of 30-kt winds was 40 n.mi. on the north side of the storm. As seen in the ESSA 8 picture taken about the time of the reconnaissance fix, the storm was classified as category 2, diameter 3 (Anderson et al. 1969); this classification called for considerably more wind speed than that in the storm.

U.S. Air Force reconnaissance on November 3 found that the maximum surface winds had increased to 60 kt

[1] Three standard flight plans are in the files of the 55th Weather Reconnaissance Squadron for the different Lark Fan tracks.

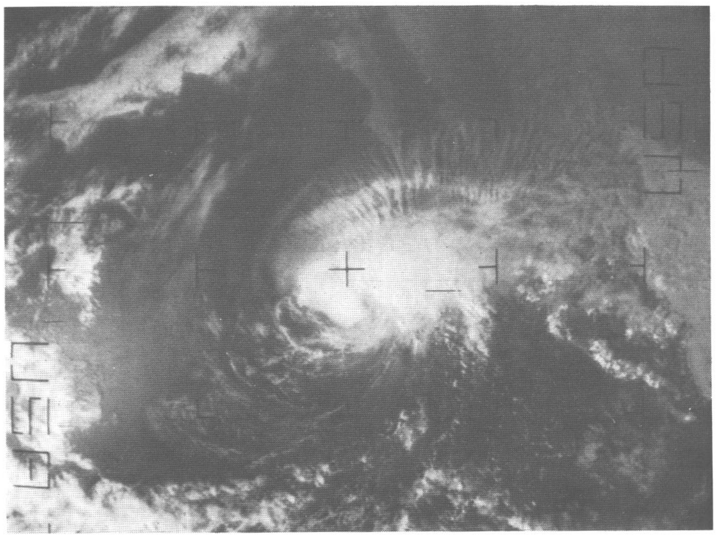

FIGURE 14.—ITOS 1 view, orbit 3559, on Nov. 3, 1970, depicting Selma with wave clouds around the north side.

and the minimum surface pressure had fallen to 995 mb; the center was located about 40 n.mi. south of Socorro Island. The storm was moving northeast, having recurved from the west-northwest path of the previous day. The well-defined wall clouds were closed about the eye, and there were scattered cumulonimbus in the southwestern and western quadrants. Cirrostratus (25,000-ft base and 35,000-ft top) covered much of the storm. Pictures provided negligible additional information, but the ITOS 1 picture at 2234 GMT showed a very unusual cloud formation around the northern periphery of the storm (fig. 14). The thought is that the wave pattern in the clouds developed as a result of a combination of turbulent low-level easterly flow from the Mexican Plateau (probably containing a standing wave pattern) and overrunning west-southwest winds that carried cirrostratus and altostratus in which waves had been induced. Winds at 300 mb in the area were about 25 kt and were from the west-southwest.

The storm then weakened. The ESSA 8 picture at 1742 GMT on November 4 still showed profuse cirrostratus outflow from the central and eastern parts of the storm; but in the west semicircle, much of the lower cloud spiral was exposed. The ITOS 1 picture at 2136 GMT showed that the cirrostratus cap seemed to be shifting to the northeast to expose a larger part of the low cloud spiral. The next Air Force reconnaissance at 0021 GMT on November 5 reported 45-kt maximum surface winds in the storm. The eye was circular (15 n.mi. in diameter), open southwest to southeast, and clear of low and middle clouds; there was, however, a heavy cirrus overhang from the east.

Just after the reconnaissance flight fixed its position at 20°30′N, 108°40′W, Selma made an abrupt turn toward the west-northwest and crossed the 110th meridian for the third time. The change in movement apparently involved a shearing apart of the storm, with the top of the storm continuing to move northeastward. This opinion is supported by the ESSA 8 picture of 1645 GMT on November 5 that showed a narrow-banded spiral of lower clouds free of upper clouds, except in the east semicircle. Here, from 50 n.mi. east of the center, a large cirrostratus shield covered the mouth of the Gulf of California. Only a weak depression was left on the morning of the 6th; it rapidly decreased in circulation. Remains of the cloud spiral, however, could still be identified south of Baja California in the pictures taken on the afternoon of the 8th.

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