ANNUAL SUMMARY

Eastern North Pacific Hurricane Season of 1998

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ABSTRACT

The 1998 eastern North Pacific hurricane season is reviewed. There were 15 tropical cyclones, consisting of nine hurricanes, four tropical storms, and two tropical depressions. During 1998, two tropical cyclones made landfall; Hurricane Isis made two landfalls in Mexico while Tropical Depression Javier dissipated near Cabo Corrientes, Mexico.

1. Introduction

The most prominent characteristic of the 1998 eastern North Pacific hurricane season was the below-normal number of landfalling tropical cyclones. On average, three or four tropical cyclones strike the coast of Mexico each year but only two tropical cyclones made landfall during 1998. Hurricane Isis made two landfalls in Mexico, it passed over southern Baja California and then finally passed onshore near Los Mochis, where it claimed 14 lives. Weakening Tropical Depression Javier dissipated over land near Cabo Corrientes, Mexico, without consequence.

The 1998 eastern North Pacific hurricane season also featured United States Air Force Reserve (USAFR) reconnaissance flights into Hurricanes Lester and Madeline, which threatened the coast of Mexico. These flights were coordinated through the government of Mexico and served to test flight clearance procedures in Mexican airspace.

The average numbers of tropical storms and hurricanes per year in the eastern North Pacific basin are 16 and 9, respectively. While the number of named storms in 1998 was below average (13), the number of hurricanes was equal to the long-term average. Of the nine, six attained category 3 or higher status on the Saffir–Simpson hurricane scale (SSHS) (Simpson 1974) with estimated 1-min sustained winds ≥100 kt. A summary of 1998 tropical cyclone statistics appears in Table 1.

The season got off to a late start with the development of the first tropical cyclone, Agatha, on 11 June. Historically, the median day for formation of the first eastern North Pacific tropical cyclone is 31 May.

Most of the tropical storms and hurricanes remained away from land on climatologically favored tracks toward the west-northwest. Prevailing steering resulted from a persistent 50-mb anticyclone located over the western United States. This feature persisted throughout most of the summer. A few tropical cyclones threatened Baja California during short periods when the strong anticyclone weakened. In most of these cases, however, the anticyclone reestablished itself and steered the storms to the west-northwest before they reached Baja California.

The development of eastern North Pacific tropical cyclones from tropical waves is common and has been extensively documented in annual summaries published by the U.S. National Weather Service National Hurricane Center (NHC) going back to the late 1960s (Simpson et al. 1969) and in more recent articles by Molinari et al. (1997, 1999). Tropical waves played a significant role in the formation of many of the 1998 eastern North Pacific tropical cyclones. These waves usually take more than a week to traverse the Atlantic and Central America after emerging from west Africa. These waves are not always clearly depicted once they move into the eastern North Pacific. In some cases, the waves interact with a cyclonic monsoon-type flow, which is a climatological feature in this region during the hurricane season. With the single exception of Hurricane Kay, the 1998 eastern North Pacific tropical cyclones formed from tropical waves that crossed Central America from the Atlantic basin. In fact, the southern portion of the tropical waves that triggered Alex, Bonnie, Danielle, and Lisa in the Atlantic were related to the development of Georgette, Javier, Isis, and Lester in the eastern North Pacific.

An analysis of the mean 850-mb flow indicates that the axis of the intertropical convergence zone (ITCZ),

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TABLE 1. Eastern North Pacific hurricane season statistics for 1998.

Number	Name	Class*	Dates**	Max 1-min wind (kt)	Min sea level pressure (mb)	Deaths
1	Agatha	T	11–16 Jun	55	993	
2	Blas	H	22–30 Jun	120	943	
3	Celia	T	17–21 Jul	50	997	
4	Darby	H	23 Jul–1 Aug	100	958	
5	Estelle	H	29 Jul–8 Aug	115	948	
6	Frank	T	6–10 Aug	40	1001	
7	Georgette	H	11–17 Aug	100	960	
8	Howard	H	20–30 Aug	130	932	
9	Isis	H	1–3 Sep	65	987	14
10	Javier	T	6–14 Sep	50	995	
11	Kay	H	13–17 Oct	65	987	
12	Lester	H	15–26 Oct	100	965	
13	Madeline	H	16–20 Oct	75	979	

* T: tropical storm, wind speed 34–63 kt. H: hurricane, wind speed 64 kt or higher.
** Dates begin at 0000 UTC and include tropical depression stage.

which is normally located south of the Gulf of Tehuantepec, shifted northward so that the axis extended from central/southern Mexico westward into the eastern Pacific between 15° and 20°N (Fig. 1). Occasionally, the eastern portion of the ITCZ extended across Central America and into the southern Gulf of Mexico. This inland shift of the ITCZ along with the proximity of the western portion of the axis to cooler waters resulted in conditions unfavorable for tropical cyclone genesis.

2. Tropical cyclone tracks and intensity

The NHC tropical cyclone ‘‘best track’’ database[1] specifies center position, the maximum 1-min sustained surface wind speed, and the minimum sea level pressure. These parameters are estimated at 6-h intervals based upon poststorm analysis of all available data. The primary sources for the analysis are the National Oceanic and Atmospheric Administration (NOAA) Tropical Analysis and Forecast Branch collocated with the NHC, the NOAA Satellite Analysis Branch, and the Air Force Weather Agency. These centers provide the NHC with real-time position and intensity estimated with the Dvorak (1984) tropical cyclone analysis technique. Essential satellite data were observed by the Geostationary Operational Environmental Satellites (*GOES-8* and *GOES-10*) and polar-orbiting satellites (Defense Meteorological Satellite Program; DMSP). It included high-resolution Special Sensor Microwave/Imager (SSM/I) 85-GHz channel data. Observations from ships and land stations supplemented these data, as did radar reflectivity images provided by the Servicio Meteorologico Nacional de Mexico and USAFR reconnaissance in Hurricanes Lester and Madeline. Figure 2 shows the 1998 eastern North Pacific tropical cyclone tracks.

[1] Track and ‘‘fix’’ data are contained in the Annual Hurricane Diskette Data Tabulation, available from the National Climatic Data Center, Federal Building, Asheville, NC 28801. Additional observations are contained in NHC preliminary reports found on the NHC Internet Web site at address *http://www.nhc.noaa.gov*

3. NHC forecast verification

The NHC began operational forecasting of eastern North Pacific tropical cyclones in 1988. Every 6 h; the NHC issues its ‘‘official’’ tropical cyclone track and intensity forecast for periods extending to 72 h. The quality of the forecasts is evaluated using the postseason best track database.

Track error is defined as the great-circle distance between forecast and best-track position of the tropical cyclone center. Table 2 shows that the 1998 average official track errors were below the 1988–97 averages for all forecast periods.

Table 3 displays two intensity errors. The mean error is the algebraic difference between the forecast and best-track maximum 1-min wind speed. A positive error means that the forecast wind speed is higher than the best-track value while a negative error means that the forecast is lower. The second intensity error is the absolute value of the difference without regard to its sign. The sign of the mean error represents the forecast bias, whereas the mean absolute error represents the average magnitude of the error. Table 3 shows that official mean absolute intensity forecast errors for 1998 were 10%–20% below the 1990–97 average at 0–36 h and 5%–10% below at 48 and 72 h. Although the bias was smaller than the long-term average, it nonetheless increased with time, and exceeded one SSHS category for periods greater than 36 h. The Statistical Hurricane Intensity Forecast Model (SHIFOR) also outperformed its 1990–97 average.

4. Tropical storms and hurricanes of 1998

a. Tropical Storm Agatha, 11–16 June

A poorly defined tropical wave crossed Central America during 7 and 8 June, accompanied by cloudiness and

TABLE 2. Comparison of 1998 eastern North Pacific official and CLIPER (Climatology and Persistence track model) average track forecast errors (rounded to the nearest n mi) for a homogeneous sample (excluding extratropical and tropical depression stages), with 1989–98 10-yr average. A forecast error is defined as the great-circle distance between the forecast and postanalysis best-track positions for the same time.

	Forecast period (h)					
	0	12	24	36	48	72
1998 Avg						
Official	9	35	68	92	110	160
CLIPER	9	35	71	104	135	202
No. of cases	215	214	190	166	144	112
1988–97 avg						
Official	13	39	71	105	137	195
CLIPER	13	41	77	118	157	227
No. of cases	2532	2527	2266	1998	1755	1337
1998 avg departures (%) from 1988 to 1997						
Official	−31	−10	−4	−12	−20	−18
CLIPER	−31	−15	−8	−12	−14	−11
1998 error range	6–21	24–48	44–121	61–265	68–186	90–314

a few thunderstorms. As the wave moved westward, a broad low- to middle-level circulation developed a few hundred miles south of the Gulf of Tehuantepec, Mexico. However, the convection was disorganized and well removed from several smaller centers of circulation embedded within the system. Gradually, a dominant center of circulation became better defined. Banding features developed, and the system was classified as a tropical depression at 1200 UTC 11 June.

The depression did not become more organized during the next couple of days. Then, a second tropical wave merged with the circulation. The system then strengthened and was classified as a tropical storm. Agatha's peak winds were estimated to be 55 kt at 0000 UTC 14 June, just before the cyclone moved over cooler waters, and began to weaken.

Through most of Agatha's lifetime, the strong midlevel ridge was anchored over the Gulf of Mexico and extended westward across Baja California. Wind around its south side steered Agatha generally toward the west-northwest.

b. Hurricane Blas, 22–30 June

Blas may be traced to a tropical wave that crossed the west coast of Africa on 8 June. Although the wave spawned intermittent clusters of convection, it remained generally indistinct during its passage across the Atlantic and Caribbean. Cloudiness and convection increased off the Pacific coast of Central America on 19 June in response to the wave. The first satellite tropical cyclone classifications were received on 20 June. Convective banding increased as a broad cyclonic circulation became established. A tropical depression formed about 500 n mi south of the Gulf of Tehuantepec at 0000 UTC 22 June. During the first few days of its existence, it moved generally west-northwestward at 10 kt. This

TABLE 3. Comparison of official and SHIFOR maximum 1-min wind speed forecast errors (rounded to the nearest 0.1 kt) for tropical storms and hurricanes in the eastern North Pacific for 1998 with 1990–97 8-yr average. Also shown is the range of wind speed forecast errors (kt) for each forecast period. Error = forecast − observed.

	Forecast period (h)					
	0	12	24	36	48	72
1998						
1998 Mean	−0.7	0.0	−0.2	−3.2	−7.4	−8.3
1998 mean absolute	2.5	6.1	10.9	14.4	17.6	19.6
SHIFOR	2.5	7.4	11.4	14.0	16.1	17.2
No. of cases	215	214	190	166	144	112
1990–1997						
1990–97 Mean	−0.9	−1.4	−2.3	−3.9	−5.6	−5.9
1990–97 Mean Absolute	3.1	7.3	12.4	16.2	18.9	21.5
1990–97 SHIFOR	3.1	8.2	13.4	17.6	20.6	23.9
No. of cases	2148	2144	1932	1724	1521	1171
1998 departures (%) from 1990 to 1997 mean absolute error						
Official	−19	−16	−12	−11	−7	−9

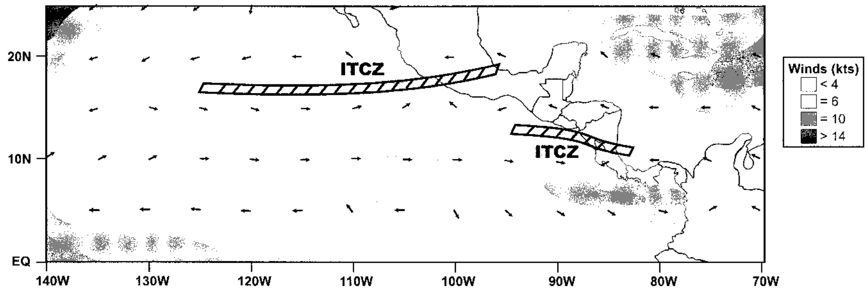

FIG. 1. Mean ITCZ location for Aug and Sep 1998 based on composite mean 850-mb winds (kt) from NCEP–NCAR reanalysis.

track roughly paralleled the southwest coast of Mexico, with the center 250–300 n mi offshore.

Deep convection concentrated near the circulation center. The depression strengthened into Tropical Storm Blas about 350 n mi south of Puerto Angel, Mexico, at 1200 UTC 22 June. Convective banding increased and Blas became a hurricane about 300 n mi south-southwest of Acapulco, Mexico, at 1800 UTC 23 June. As the upper-level outflow became well established, Blas intensified. An eye appeared in satellite imagery on 24 June. Strengthening continued and it was estimated that Blas reached its peak intensity of 120 kt and 943 mb near 0600 UTC 25 June about 500 n mi south-southeast of the southern tip of Baja California. The eye remained visible for a few more days, although surrounding cloud-top temperatures gradually warmed.

A deep-layer-mean ridge to the north turned Blas on a more westward track by 26 June. This movement persisted through the rest of its life. Blas moved over cooler water and gradually weakened to a tropical depression at 0000 UTC 30 June. A low-level cloud swirl continued westward for several more days, passing a few hundred nautical miles south of the Hawaiian Islands on 5 July.

Between 0000 and 0600 UTC 25 June, objective Dvorak T numbers ranged from 6.0 (115 kt) to 7.0 (140 kt). The highest 3-h average objective Dvorak T numbers at these times are the basis for estimating the peak intensity near 0600 UTC on 25 June. From 0315 to 1900 UTC 25 June, a new objective technique developed at the University of Wisconsin (UW) (Velden et al. 1998) consistently estimated the intensity at approximately 125 kt. Although this new scheme shows promise, it will not replace the operational subjective technique until after further tests with ground truth.

The Associated Press attributed four deaths in the Mexican state of Michoacan to Blas. Three boys and their grandmother living in a wood and cardboard home in the village of El Chaparro were killed in a landslide. At the time the deaths occurred, late on 23 June, the center of Blas was more than 250 n mi offshore and the main cloud shield in satellite pictures was offshore as well. The NHC is not directly attributing these deaths to the hurricane.

c. Tropical Storm Celia, 17–21 July

Celia was a short-lived tropical storm that briefly threatened southern Baja California. It formed from a tropical wave first identified on 1 July off the west coast of Africa. This wave moved westward across the tropical Atlantic at 15 kt with no development. It entered the eastern Caribbean Sea on 7 July. As it continued westward at low latitudes across the Caribbean Sea, its development was precluded by strong vertical wind shear. On 11 July, the wave crossed Central America. On 13 July, convective clouds began to show definite signs of organization with a possible center near 8°N, 98°W. Shortly thereafter, development ceased, as the cloud pattern remained no better organized. There was little change as the cloud cluster moved west-northwestward, until 16 July, when the convective bands associated with the disturbance became more curved and some locally heavy rains spread over the coast of southern Mexico. The following day, development was rapid. Based partially on a ship report, it is estimated that a 40-kt tropical storm had formed by 1200 UTC 17 July. Based on backward extrapolation and satellite imagery, it is estimated that this system had developed into a tropical depression about 6 h earlier, around 130 n mi south of Manzanillo, Mexico.

After becoming a tropical storm, Celia moved northwestward toward Cabo San Lucas at the southern tip of Baja California. However a same mid- to upper-tropospheric anticyclone to the north forced a more west-northwestward motion. Celia's center passed about 130 n mi south-southwest of Cabo San Lucas early on 18 July. Later that day, the tropical cyclone became better organized and reached its peak intensity of 50 kt. By 19 July, deep convection associated with Celia had diminished. A midlevel ridge along 30°–35°N latitude induced a mainly westward movement, and Celia gradually spun down over cooler sea surface temperatures, weakened to a tropical depression on 20 July, and dissipated early on 21 July.

Celia was upgraded directly to a tropical storm based on a report from ship *KGTI*, with winds of 100°/45 kt at 18.5°N, 104.6°W at 1200 UTC 17 July. Another ship, *4XGX*, reported winds of 210°/40 kt at 18.8°N, 104.7°W

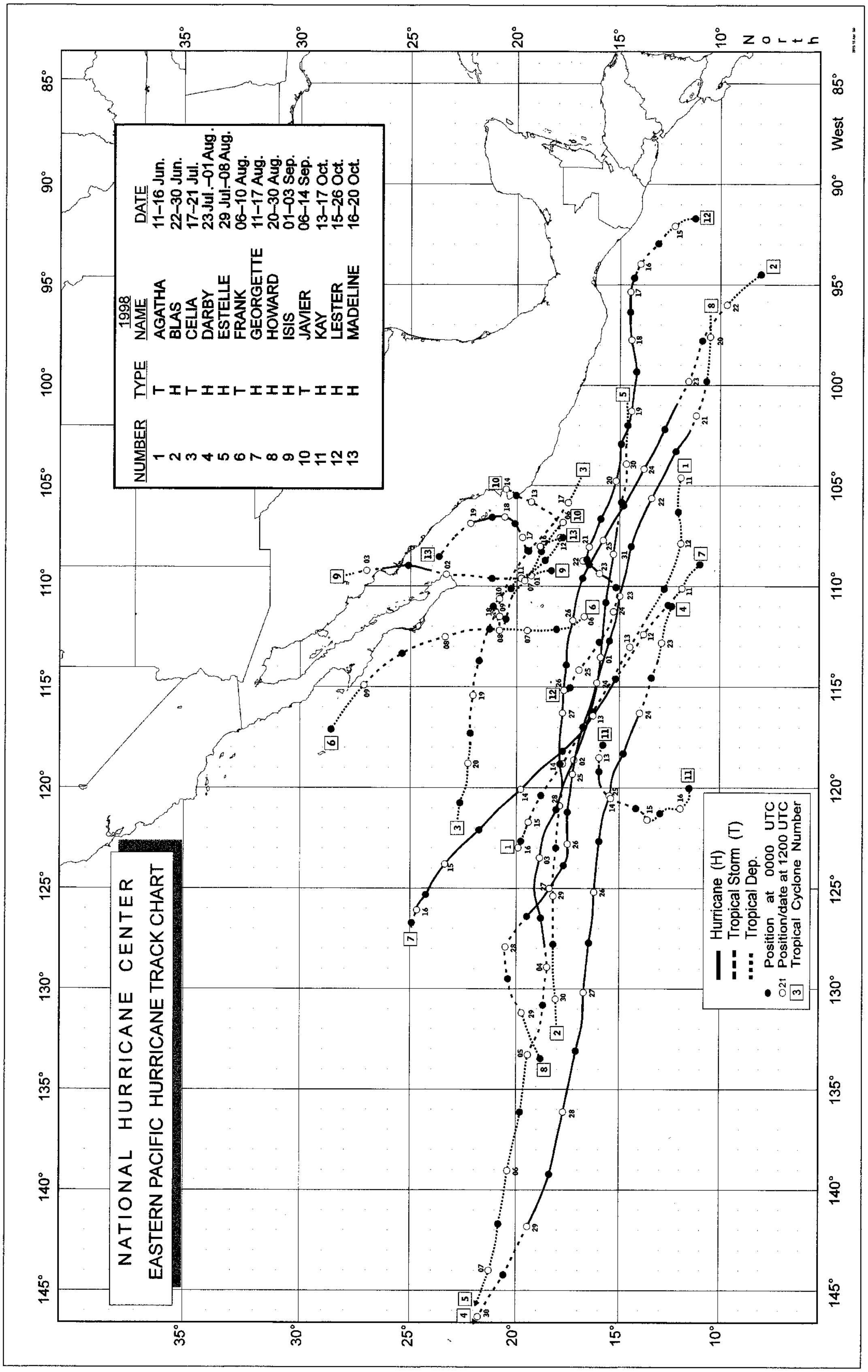

FIG. 2. Eastern North Pacific tropical storm and hurricane tracks for 1998.

and 130°/50 kt at 19.4°N, 105.6°W at 1200 and 1700 UTC 17 July. These velocities appear to have been estimates. Based on the subsequent evolution of the storm, 45 and 50 kt seem to be high. At 1200 UTC 18 July, another ship, *VRUZ*, reported 130°/35 kt winds at 22.9°N, 109.0°W, about 60 n mi east of Cabo San Lucas. No reports of tropical storm force winds were received from Baja California.

A tropical storm warning was issued for extreme southern Baja California from La Paz southward at 0300 UTC 18 July and discontinued at 1500 UTC.

d. Hurricane Darby, 23 July–1 August

Hurricane Darby formed from a tropical wave that generated little cloudiness between 4 and 16 July during its passage across the North Atlantic and Caribbean. Convection began to increase on 19 July, when the system passed about 300 n mi to the south of Acapulco, Mexico. Two days later, the cloud pattern displayed some curvature on satellite pictures. The disturbance became sufficiently well organized and it is estimated that it became a tropical depression around 0000 UTC on 23 July. It was then centered about 625 n mi to the south of the southern tip of Baja California.

The ridge extending westward from an anticyclone over the southwest United States was the dominant large-scale circulation feature during Darby's development. That feature supported a steering current that drove the tropical cyclone toward the west or west-northwest at about 10–15 kt for nearly a week. Early in this period, the cyclone strengthened quickly. The convection became more concentrated and outflow aloft increased over the western semicircle. The depression became Tropical Storm Darby at 1800 UTC on 23 July. Just 36 h later, Darby reached SSHS category 3 intensity with a 10–15 n mi wide eye. On 25–26 July, the eye disappeared in geostationary satellite imagery and then reappeared with a diameter of 20–30 n mi. This sequence of events appeared to be an eyewall replacement cycle. During this period, Darby's analyzed winds decreased a little below 100 kt and then returned to that level.

Darby was probably strongest, with 100-kt winds and a minimum pressure of 958 mb, near 1800 UTC on 26 July when objectively determined T numbers reached their peak. The hurricane stayed nearly that strong until early on 28 July when a steady, 4-day weakening began as Darby moved over colder water and encountered increasing southwesterly vertical wind shear. On 29 July, Darby was downgraded to a tropical storm by the Central Pacific Hurricane Center (CPHC), shortly after the center crossed 140°W and entered its area of responsibility. The analyses from CPHC show Darby dissipating about 300 n mi to the north of Honolulu, Hawaii, early on 1 August.

e. Hurricane Estelle, 29 July–8 August

Hurricane Estelle was the third major hurricane in the eastern North Pacific basin during 1998. It can be traced to a tropical wave that crossed the west African coast on 18 July. It crossed the Atlantic uneventfully with sporadic convection and no signs of development. Rawinsonde data from St. Martin showed that the wave passed through the eastern Caribbean on 24 July. Subsequent upper-air observations from Grand Cayman and Key West, Florida, showed the wave passage through the western Caribbean and the southeast Gulf of Mexico on 26 July. After crossing Central America, the wave emerged into the eastern Pacific on 27 July. Early on 29 July, Dvorak classifications on the system began when the disturbance was located about 200 n mi south-southeast of Acapulco, Mexico. By the afternoon of 29 July, visible satellite imagery showed distinct banding. On this basis, the system was estimated to have become a tropical depression at 1800 UTC 29 July about 150 n mi southeast of Manzanillo, Mexico. The depression continued to become better organized through the evening with increasing convection and well-defined upper-level outflow. It was upgraded to Tropical Storm Estelle at 0600 UTC 30 July.

Estelle continued to intensify on 30 July and reached hurricane strength at 0600 UTC 31 July about 480 n mi south-southeast of Cabo San Lucas, Mexico. For the next seven days, Estelle moved on a general west-northwestward course under the influence of the large mid-tropospheric anticyclone. Intensification continued. A well-defined eye, 20–30 n mi in diameter, became evident in both visible satellite imagery and SSM/I 85-GHz channel data during the afternoon of 1 August. Estelle is estimated to have reached a peak intensity of 115 kt at 0600 UTC 2 August. Estelle began to weaken and by the afternoon of 2 August, the eye was no longer discernable in satellite imagery; and the deep convection had diminished. Over the next several days, the system continued to weaken while it moved on a general west-northwestward course over progressively cooler waters. As a depression, Estelle maintained a well-defined low-level circulation center. Upper-level southwesterly vertical wind shear, induced by an upper-level trough near the Hawaiian Islands, hampered deep convective development. The system dissipated on the evening of 8 August about 500 n mi east-northeast of Honolulu, Hawaii.

In addition to the standard satellite-based Dvorak intensity estimates derived from the GOES and DMSP satellites, the European Remote Sensing Satellite (*ERS-2*) polar-orbiting satellite made a partial pass over Estelle on 4 August. The *ERS-2* scatterometer winds were used to estimate the 34-kt wind radii.

f. Tropical Storm Frank, 6–10 August

Satellite imagery showed an area of cyclonic circulation associated with a tropical wave over west-central

Africa on 19 July. The system moved westward and was observed as a distinct midlevel cloud rotation south of the Cape Verde Islands on 22 July. Thereafter, the wave became less distinct. It continued westward and crossed Central America on 31 July. Convection then began to increase but it was not until 4 August that the cloud pattern showed some organization and satellite classifications began. Based on ship reports and satellite imagery, it is estimated that the system became a tropical depression at 1200 UTC 6 August when it was located about 480 n mi south of the southern tip of Baja California.

The depression moved on a general northward track, steered by the flow between a midlevel trough just west of the U.S. west coast and a high over Mexico. The depression reached tropical storm status at 0000 UTC 8 August and became a threat to portions of Baja California. Frank's maximum intensity was estimated at 40 kt with a minimum pressure of 1001 mb at 0000 UTC on 9 August. As Frank turned toward the north-northwest, a portion of its circulation remained over Baja California. It then reached cooler waters and gradually weakened.

Winds of 30–35 kt reported by the ship *C6LF9* were used to upgrade the tropical depression to a tropical storm. As Frank approached Cabo San Lucas, the system was under surveillance by Mexican radar there. The radar data were helpful in positioning the center of the storm and the rainbands. Heavy showers and gusty winds were observed primarily in the Gulf of California. Moisture from the storm reached the southwestern United States. Since Frank was a threat to Baja California, tropical storm watches and warnings were required for a portion of this area.

g. Hurricane Georgette, 11–17 August

Georgette's origin can be traced back to a tropical wave that appeared in the far eastern tropical Pacific Ocean on 4 August. This wave was likely the same one that triggered Tropical Storm Alex in the Atlantic about a week earlier. The associated area of disturbed weather moved slowly westward. By 9 August, satellite images showed evidence of a low-level circulation 600 n mi south of Manzanillo, Mexico. On 11 August, as banding developed, the cloudiness separated from the ITCZ, and the system was identified as a tropical depression.

Throughout its existence, it moved on a west-northwestward to northwestward track, around the periphery of a subtropical high pressure ridge. This track kept the center well offshore. The forward speed was 10–12 kt. Near dissipation on 17 August, the motion became a slow westward drift.

Intensification was fairly steady. Georgette became a tropical storm late on 11 August and, based on banding features, a hurricane early on 13 August. An eye, 35 n mi in diameter, formed on 13 August and based on satellite intensity estimates, the winds reached 100 kt on 14 August. Cloud tops soon started to warm and weakening continued until Georgette dissipated on 17 August. There was a small convective burst on 15 August, after convection had been decreasing for some time, but this event did not appear to significantly change the weakening trend.

h. Hurricane Howard, 20–30 August

Hurricane Howard was the strongest hurricane of the 1998 eastern North Pacific hurricane season. Its development can be traced to a tropical wave that crossed the coast of Africa on 7 August. The wave spawned intermittent clusters of convection as it moved across the Atlantic at low latitudes, and then remained indistinct during its passage over the Caribbean and northern South America. Cloudiness and convection increased off the Pacific coast of Central America on 17 August.

The first satellite classifications were received on 18 August. Animated satellite imagery indicated a broad low-level cyclonic circulation with intermittent bursts of deep convection on 18 and 19 August. The deepest convection became more persistent near the circulation center. It is estimated that the disturbance became a tropical depression at 0600 UTC 20 August about 300 n mi south of Puerto Angel, Mexico. The tropical cyclone moved generally west-northwestward near 10 kt in response to deep-layer-mean steering.

Banding became more pronounced. The depression strengthened into Tropical Storm Howard at 0000 UTC 21 August about 375 n mi south of Acapulco, Mexico. The center of the tropical cyclone became more centrally embedded within the deep convection. Howard is estimated to have become a hurricane at 1800 UTC 21 August, about 450 n mi south-southeast of Manzanillo, Mexico. As the upper-level outflow became better established, Howard continued to intensify. An eye appeared in satellite imagery on 22 August. Rapid strengthening occurred. Howard became an SSHS category 3 hurricane by 1200 UTC. It is estimated that Howard reached its peak intensity of 130 kt and 932-mb minimum central pressure near 0000 UTC 23 August about 525 n mi south-southeast of the southern tip of Baja California (see Fig. 3). Howard's intensity neared the top end of category 4, with a small eye embedded within a very cold central dense overcast. Although the eye gradually became larger and some intensity fluctuations occurred, Howard appears to have remained a major hurricane (≥category 3) for 4 days.

Howard moved over cooler water and gradually weakened. It was a dissipating tropical depression on 30 August about 1200 n mi west-southwest of the southern tip of Baja California. A low-level cloud swirl persisted for a few more days.

The highest official Dvorak T number was 6.5 (127 kt). However, the highest UW objective Dvorak T number was 7.0 (140 kt) between 1345 UTC 22 August and 0300 UTC 23 August. The highest 12-h weighted-av-

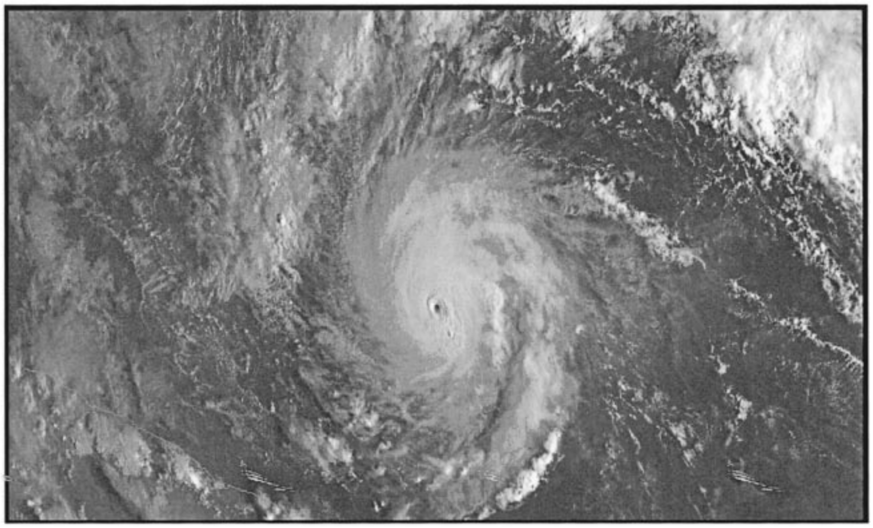

Fig. 3. *GOES-10* 2-km visible image of Hurricane Howard at 0000 UTC 23 Aug 1998, near the cyclone's peak intensity.

erage objective Dvorak T number peaked at 7.0 near 0000 UTC 23 August. This is the basis for estimating the peak intensity at this time.

i. Hurricane Isis, 1–3 September

Isis made two landfalls in Mexico; the first in southern Baja California as a tropical storm, and the second near Los Mochis as a category one hurricane.

A tropical wave, which on 19 August produced the tropical depression that became Atlantic Hurricane Bonnie, moved westward across the Caribbean between 21 and 24 August and crossed Central America on 25 August. As the wave moved into a large lower-tropospheric cyclonic circulation (or, at least, cyclonic turning) over southern Mexico and the adjacent waters, it slowed. The resulting broad area of disturbed weather between 90° and 110°W persisted from 26 to 29 August. A more concentrated area of low-level cyclonic rotation appeared on 29 August a little over 500 n mi south-southeast of Cabo San Lucas. There was little change for the next day or two. On 31 August, the system developed two main areas of dense cloudiness a few degrees northeast and southwest of the center. By 0000 UTC 1 September, the low-cloud circulation centered slightly less than 300 n mi south of Cabo San Lucas was sufficiently well defined so that the system could be designated as a tropical depression, even though deep convection was still not well organized.

It intensified gradually as it moved slowly north-northwestward. Ship observations indicated that the cyclone strengthened into Tropical Storm Isis by 1800 UTC 1 September. Isis moved northward at about 10 kt in a southerly steering flow supported by a 500-mb trough, extending south-southwestward from the California–Arizona border. It made its first landfall over extreme southeastern Baja California at 1200 UTC 2 September. Isis then moved slightly east of north, over the Gulf of California, and strengthened to a 65-kt hurricane with an eye apparent in visible satellite imagery. The hurricane maintained this strength until it made final landfall at Topolobampo, Mexico, near Los Mochis, around 0300 UTC 3 September. Isis weakened to a tropical storm a few hours after landfall, and to a depression by 1800 UTC 3 September. The system dissipated over the mountains of Mexico.

Islas Marias reported south-southwesterly winds at a 10-min average speed of 40 kt at 0000 UTC 2 September. San Jose del Cabo reported 270°/20 kt (10-min average) with gusts to 40 kt at 1445 UTC 2 September. Only scant information is available concerning Isis's impact on land. According to press reports, Isis caused 14 deaths in Mexico, and destroyed hundreds of homes.

j. Tropical Storm Javier, 6–14 September

The formation of Tropical Storm Javier was likely associated with a tropical wave that crossed the coast of Africa on 22 August. The northern portion of the wave spawned Hurricane Danielle in the Atlantic; the southern part of the wave remained relatively inactive and difficult to track during its westward passage across the Atlantic and Central America. Extrapolation of the wave's track places it near Acapulco on 3–4 September, and it is there that deep convection then began to develop.

Javier appears to have been initiated during the passage of the wave through a broad area of low pressure and monsoonlike low-level cyclonic flow that occurs episodically just southwest of Mexico. The disturbance became better defined on satellite pictures by 5 September and the first Dvorak T numbers were assigned that

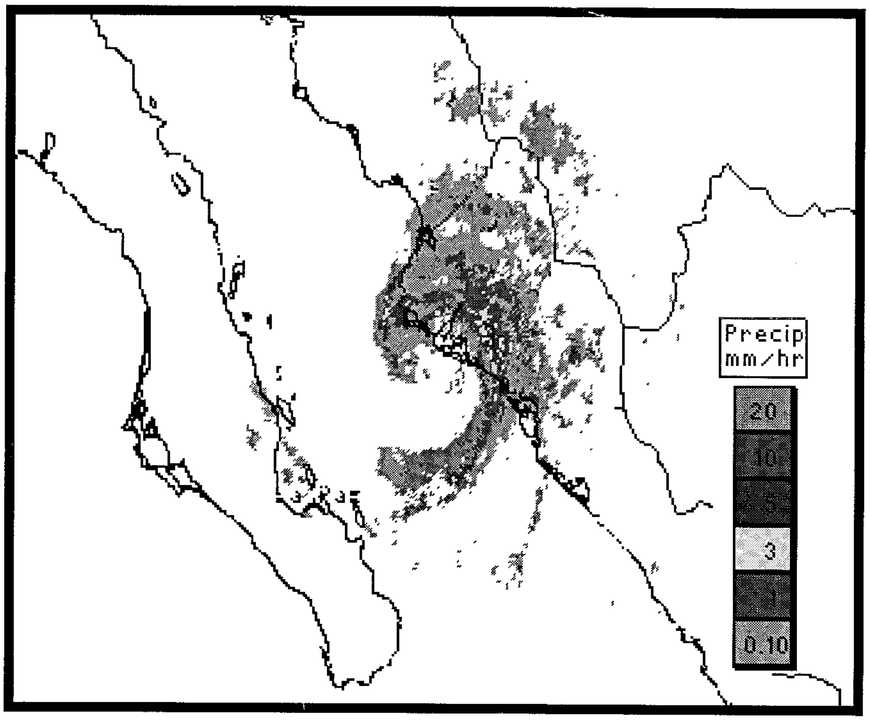

FIG. 4. Radar reflectivity image of Hurricane Isis just before landfall from Guasave, Mexico, radar. Image provided by the Servicio Meteorologico Nacional de Mexico.

day when it was centered about 150 n mi offshore. Surface pressures were then as low as 1000–1005 mb. Although the disturbance initially moved toward the northwest at about 10 kt, steering currents weakened and it meandered slowly for the next 10 days between Manzanillo, Socorro Island, and Cabo San Lucas.

Deep convection became organized and persistent enough for Javier to be designated as a tropical depression on 6 September, and a tropical storm the following day. The storm formed in an environment of easterly to northeasterly vertical wind shear that probably limited development. Banding features never became especially prominent in Javier. The storm's maximum estimated intensity, 50 kt, coincided with a burst of thunderstorm activity over the cyclone center on 8 September. That convective pattern was short lived, however. The low-level cloud center became exposed outside the diminishing deep convection early on 9 September. Although spots of deep convection occasionally reappeared, Javier weakened to a tropical depression during the afternoon of 9 September and continued to weaken slowly through 11 September. At times, it became difficult to distinguish it from a broader area of disturbed weather in which it was embedded.

A brief resurgence of thunderstorms occurred near the circulation center on 12 September and observations from a nearby ship indicate that Javier briefly returned to tropical storm strength, with maximum winds near 45 kt. Convection again became sporadic and the system had weakened back to a tropical depression when it drifted ashore about 30 n mi south-southeast of Cabo Corrientes on 14 September. It dissipated later that day over land.

Data from an overpass of the *ERS-2* near 0000 UTC on 10 September was helpful in analyzing the cyclone. The ship *3EMJ6* reported winds of 39 and 44 kt at 1900 and 2100 UTC, respectively, on 12 September, within about 25 n mi of the center.

An observation of 1000.6 mb and westerly winds of 27 kt at Socorro Island, 90 n mi from the center of the cyclone, were used operationally by the NHC to help establish when the system reached tropical storm strength.

The NHC is not aware of damages or casualties incurred from Javier.

While watches and warnings were neither issued nor necessary for this cyclone, public advisories issued by the NHC did contain cautionary statements for small craft along coastal areas of Mexico adjacent to the storm.

k. Hurricane Kay, 13–17 October

Kay developed about 600 n mi southwest of the southern tip of Baja California from a tropical disturbance on the ITCZ. Initially, there was a small low-level circulation that moved northward away from the ITCZ, but the convection was weak and disorganized. The showers gradually became concentrated and Dvorak classifications suggested that a tropical depression formed about 0000 UTC 13 October. Steady intensification followed and an eye developed. Kay reached hurricane status, with estimated maximum winds of 65 kt, at 1800 UTC on 13 October. Subsequently, the pinhole eye disappeared and a gradual weakening ensued. Several bursts of deep convection occurred before Kay dissipated.

Kay remained within a weak steering flow pattern. Consequently, it moved very little during its lifetime and made a partial cyclonic loop of 300 n mi in diameter before it merged back into the ITCZ.

l. Hurricane Lester, 15–26 October

The tropical wave responsible for Hurricane Lester moved off the west African coast on 29 September. This wave produced Hurricane Lisa in the tropical Atlantic midway between Africa and the Lesser Antilles on 5 October. The wave itself continued westward. It crossed Central America on 11 and 12 October as a poorly organized cluster of thunderstorms. A low-level circulation center first appeared in satellite imagery on 13 October, in the Pacific about 150 n mi south of the border between El Salvador and Guatemala. As this feature moved slowly northwestward, convection near the center increased and a banding feature formed. It is estimated that a tropical depression formed at 0000 UTC on 15 October about 175 n mi south of the coast of Guatemala. By 0000 UTC on 16 October, the depression strengthened to Tropical Storm Lester. Lester moved to about 100 n mi south of the Guatemala and Mexico coasts on 15 October as a tropical storm.

Lester became a hurricane on 16 October and remained one until 23 October. Its closest point of approach to the coast was about 60 n mi south of Puerto Angel, Mexico, on 17 and 18 October. Its maximum winds reached 90 kt on 17 October and remained near that speed through 22 October, when it briefly reached 100 kt. It is possible that tropical storm force winds and some heavy rainfall reached the coast between the Mexico–Guatemala border and Punta Maldonaldo. It is not believed that Lester was close enough for hurricane conditions to reach the coast.

Lester's track generally paralleled the coast of Mexico from 15 through 20 October. The track turned southwestward on 22 October and northwestward on 24 October. Lester dissipated about 450 n mi southwest of the southern tip of the Baja Peninsula on 26 October. Overall, the motion was toward the west-northwest at less than 10 kt. This is consistent with the steering associated with a high pressure ridge northeast of Lester. The storm nearly stopped for several hours on 17 October when a short-wave trough passed by to the north. Another short-wave trough stalled Lester again on 22 October. A ridge then built to the north pushing Lester toward the southwest for a day, and then the northwestward track resumed.

A USAFR reconnaissance aircraft flew into the center on 17 and 18 October. The highest wind speed at 700 mb and the minimum central surface pressure observed were 98 kt and 973 mb on 18 October.

There have been no observations received of strong surface winds on the coast of Mexico. A series of radar images from the Servicio Meteorologico Nacional de Mexico radar at Puerto Angel (not shown) showed the northern half of an eye wall offshore on 17 and 18 October. There were no reports of casualties or damage.

The Servicio Meteorologico Nacional de Mexico issued watches or warnings from Sipacate, Guatemala, westward to Punta San Telmo, Mexico. Tropical storm warnings were issued east of Puerto Arista, Mexico, and hurricanes warnings were issued to the west of Puerto Arista to Acapulco. A hurricane watch was issued west of Acapulco to Punta San Telmo.

m. Hurricane Madeline, 16–20 October

Madeline can be traced to a tropical wave that crossed the coast of Africa on 25 September. The wave produced intermittent clusters of convection as it moved across the Atlantic and Caribbean. It crossed Central America on 5 and 6 October. Convection increased near the Gulf of Tehuantepec, and Dvorak classifications began on 9 October. Satellite classifications of the disorganized cloudiness off the southwest coast of Mexico temporarily ceased on 11 October. Classifications resumed on 15 October. A tropical depression formed about 200 n mi west-southwest of Manzanillo, Mexico, near 0000 UTC 16 October.

Under diffluent flow aloft, the deep convection became more concentrated. Satellite estimates suggest that the depression strengthened into Tropical Storm Madeline about 150 n mi southwest of Cabo Corrientes, Mexico, at 1200 UTC 16 October. Banding features became more pronounced and Madeline became a hurricane at 1800 UTC 17 October about 85 n mi west-southwest of Cabo Corrientes. Upper-level outflow remained well established, and it is estimated that the maximum winds in Madeline exceeded 75 kt between 1200 UTC 18 October and 0000 UTC 19 October. Satellite pictures showed a hint of an eye on 18 October, and the last report from a reconnaissance aircraft reported that the minimum central pressure was continuing to drop late that day. The best track estimates that the lowest pressure of 979 mb occurred at 0000 UTC 19 October.

As upper-level shear increased during 19 October, the cloud pattern became less organized. Madeline weakened to a tropical storm by 1200 UTC 19 October, and to a tropical depression 12 h later, at which time only a swirl of low clouds remained midway between the southern tip of Baja California and the mainland of Mexico. The center of the tropical cyclone never crossed the coast, although rainbands moved over portions of southwestern Mexico.

Throughout Madeline's lifetime, the steering currents were relatively weak. In the early stages, Madeline was located near the western edge of an east–west-oriented midlevel ridge; this resulted in a general northward motion of the cyclone. A midlevel trough approaching from the west on 17 and 18 October appears to have slowed the northeastward motion. The trough did not move the tropical cyclone far before shearing caused Madeline to weaken and the lower-level steering eventually turned it toward the northwest.

In addition to the satellite estimates, observations were received from U.S. Air Force Hurricane Hunter aircraft. The lowest minimum central pressure reported was 980 mb at 2153 UTC 18 October during the second of two missions into the hurricane. The maximum wind measured was 76 kt at 10 000 ft at 2028 UTC on 18 October. A Global Positioning System dropwindsonde reported a near-surface wind of 73 kt near this time.

5. Summary

The 1998 eastern North Pacific hurricane season was marked by below-normal tropical cyclone activity and only two landfalling systems. Hurricane Isis made landfall near Los Mochis, Mexico, claiming 14 lives while Tropical Depression Javier dissipated near Cabo Corrientes, Mexico, without loss of life. The 1998 eastern North Pacific hurricane season also featured USAFR reconnaissance flights into Hurricanes Lester and Madeline, while they threatened portions of the coast of Mexico.

The official 1998 average track and mean absolute intensity errors were below the 1988–97 averages for all forecast periods.

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