Eastern North Pacific Hurricane Season of 2002

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(Manuscript received 21 March 2003, in final form 1 April 2003)

ABSTRACT

The 2002 eastern North Pacific hurricane season is summarized and the year’s tropical cyclones are described. The season featured 12 named tropical storms, of which 6 became hurricanes. Five of the six hurricanes reached an intensity of 100 kt or higher. There were two landfalling cyclones, Tropical Storm Julio and Hurricane Kenna. Kenna, which made landfall near San Blas, Mexico, with winds of near 120 kt, was responsible for four deaths.

1. Overview

Tropical cyclone activity in the eastern North Pacific hurricane basin (the area north of the equator between the American continents and 140°W longitude) was below average in the year 2002. There were 12 cyclones of at least tropical storm strength (Table 1, Fig. 1). Of these, six became hurricanes. The mean seasonal totals for the period 1966–2002 were 15 named storms and eight hurricanes. Although the total of six hurricanes was below normal, there were five “major” hurricanes, one above the long-term average [a major hurricane has maximum 1-min average winds greater than 96 kt (1 kt = 0.5144 m s⁻¹), corresponding to category 3 or higher on the Saffir–Simpson hurricane scale (Saffir 1973; Simpson 1974)]. Overall activity was fairly evenly distributed over the 15 May–30 November season, with tropical cyclones forming in each month. The longest interval without a tropical cyclone was 25 days, from 27 September to 21 October. Kenna was the strongest hurricane of the season, with peak winds of 145 kt. In addition to the 12 named tropical cyclones in 2002, there were four depressions that did not reach tropical storm strength.

Eastern North Pacific tropical cyclones were directly responsible for four deaths in 2002; these resulted from Hurricane Kenna, which made landfall north of Puerto Vallarta, Mexico, near San Blas in late October. Tropical Storm Julio also made landfall in Mexico, and rains from Tropical Storm Boris caused damage even though the center of the cyclone remained offshore.

Hovmöller diagrams of twice-daily satellite images can be extremely useful in identifying the mode of tropical cyclogenesis in the eastern North Pacific. A recent illustrative example and discussion is provided by Avila et al. (2003). These diagrams reveal that the genesis of half of the named storms in 2002 (Alma, Douglas, Elida, Fausto, Genevieve, and Isele) could be clearly identified with Atlantic tropical waves traceable to the west coast of Africa. The precursor disturbances to Kenna and Lowell also crossed over from the Atlantic but did not have a clear signal in the eastern tropical Atlantic. In addition, a tropical wave likely was a contributing factor, if not the precursor disturbance, to the genesis of Boris. The association of Cristina and Hernan with Atlantic waves is uncertain. Only the genesis of Julio appears to be wholly unrelated to an Atlantic tropical wave.

August and September were relatively inactive months in 2002, as only five named storms, three fewer than normal, formed during this period. While sea surface temperatures were at or above normal over most of the basin during this time, atmospheric conditions appear to have been less favorable. Figure 2 shows the monthly anomalies of 200–850-mb vertical wind shear for the months of August and September, calculated using twice-daily analyses from the National Oceanic and Atmospheric Administration (NOAA)/National Weather Service’s Global Forecast System (GFS) and long-term means from the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis project (Kistler et al. 2001). During August, favorable (below normal) shear anomalies were confined mostly to latitudes south of the basin’s main development belt. In September, a broad band of enhanced shear, attributable to enhanced low-level westerly and northwesterly flow, covered nearly the entire basin. A small area of favorable anomalies extended northward roughly along 105°–115°W during August, and in fact, two of the three cyclones that formed during the month developed in this area.

Analyses from the NOAA Climate Prediction Center
(not shown) indicate that activity during the first half of August may also have been suppressed due to the arrival of the negative (upper-level convergence) phase of the Madden–Julian oscillation. Interestingly, the Atlantic tropical cyclone basin was unusually active during August and September, generating 11 named tropical cyclones, 5 more than normal.

Section 2 describes the 2002 season’s tropical cyclones that attained at least minimal tropical storm strength (34 kt). Weaker tropical cyclones are discussed in section 3. Section 4 presents a verification of National Hurricane Center (NHC) official forecasts.

2. Storm and hurricane summaries

The individual cyclone summaries in this section are based on NHC’s poststorm meteorological analyses. These analyses result in the creation of a “best track” database for each storm, consisting of 6-hourly representative estimates of the cyclone’s center location, maximum sustained (1-min average) surface (10 m) wind, and minimum sea level pressure. The life cycle of each cyclone (corresponding to the dates given in Table 1) is defined to include the tropical or subtropical depression stage, but does not include remnant low or extratropical stages. The tracks for the season’s tropical storms and hurricanes are shown in Fig. 1.

For most eastern North Pacific cyclones, the primary (and often sole) source of information is Geostationary Operational Environmental Satellite (GOES) and polar-orbiting weather satellite imagery, interpreted using the Dvorak (1984) technique. Several other satellite-based remote sensors play an important part in the analysis of tropical weather systems. Foremost of these is multichannel passive microwave imagery, which over the past decade has provided radarlike depictions of systems’ convective structure (Hawkins et al. 2001), and is of great help in assessing system location and organization. The SeaWinds scatterometer onboard the National Aeronautics and Space Administration’s Quick Scatterometer (QuikSCAT) satellite (Tsai et al. 2000) provides surface winds over large oceanic swaths. While the QuikSCAT does not have the horizontal resolution to determine a cyclone’s maximum winds, it can be used to estimate the extent of tropical storm force winds, and is often helpful in determining whether an incipient tropical cyclone has acquired a closed surface circulation.

For systems posing a threat to land, in situ observations are sometimes available from aircraft reconnaissance flights conducted by the 53d Weather Reconnaissance Squadron, “Hurricane Hunters,” of the U. S. Air Force Reserve Command (AFRC); in 2002 there were two such missions in Hurricane Kenna. During reconnaissance flights, minimum sea level pressures are either measured by dropsondes released at the circulation center or extrapolated hydrostatically from flight level. Surface (or very near-surface) winds in the eyewall or maximum wind band are often measured directly using Global Positioning System (GPS) dropwindsondes (Hock and Franklin 1999), but more frequently are estimated from flight-level winds using empirical relationships derived from a 3-yr sample of GPS dropwindsonde data (Franklin et al. 2003). When available, satellite and reconnaissance data are supplemented by conventional land-based surface- and upper-air observations, ship and buoy reports, and weather radars.

a. Hurricane Alma, 24 May–1 June

Alma originated from a tropical wave that moved across the west coast of Africa on 8 May and reached the eastern North Pacific Ocean on 18 May. On the following day a closed surface circulation formed along the wave axis south of Guatemala. Over the next 5 days the low moved slowly westward, but did not begin to develop significantly until 20 May, when the system
Fig. 1. Tracks of tropical storms and hurricanes in the eastern North Pacific basin in 2002. (a) The tracks of storms 1–6 and (b) storms 7–12.
encountered strong northeasterly flow from a gale area in the Gulf of Tehuantepec. The system developed into a tropical depression on 24 May about 485 n mi south-southeast of Manzanillo, Mexico.

The depression moved slowly westward for the next 2 days with little change, but then strengthened into a tropical storm about 570 n mi south of Manzanillo on 26 May. Alma turned west-northwestward and intensified, becoming a hurricane on 28 May about 680 n mi southwest of Manzanillo. Alma began moving northward around the western periphery of a subtropical ridge centered over Mexico. Steady intensification continued for the next 2 days as the hurricane turned northward, and Alma reached its peak intensity of 100 kt on 30 May when it was located about 470 n mi southwest of Cabo San Lucas, Mexico.

Alma then began to weaken while it started moving over cooler water and encountered southwesterly wind shear. The cyclone weakened to a tropical storm on 31 May and stalled as its deep convection diminished. The cyclone weakened to a depression and then dissipated on 1 June about 450 n mi southwest of Cabo San Lucas.

There were no ship or surface reports of sustained tropical storm force winds associated with Alma, and no reports of damage or casualties.

b. Tropical Storm Boris, 8–11 June

Boris (Fig. 3) was a short-lived tropical storm that brought heavy rains to portions of southwest Mexico. It appears to have developed from an interaction of a tropical wave with a broad and persistent eastern North Pacific disturbance southwest of Acapulco, Mexico. On 1 June, a broad trough of low pressure, accompanied
by a large area of showers and thunderstorms, extended from the Gulf of Tehuantepec southwestward for several hundred miles. The disturbance remained nearly stationary with little change in structure until 6 June, when convection became more concentrated about 200 n mi southwest of Acapulco. A tropical wave, which was located in the extreme southwestern Caribbean Sea on 1 June, moved slowly westward and was near the Gulf of Tehuantepec by late on 6 June. As the wave reached the disturbance on 7 June, the organization of the disturbed weather increased, and on 8 June the system developed a distinct circulation center with enough organized convection to be considered a tropical depression. At this time the center of circulation was located about 150 n mi west-southwest of Acapulco.

The depression moved to the west-northwest at less than 10 kt and strengthened during the day, reaching tropical storm status on 9 June when it was about 150 n mi south-southeast of Manzanillo. This necessitated the issuance of a tropical storm watch at 2100 UTC 8 June for the coast of Mexico from Punta San Telmo to Cabo Corrientes.1 Boris reached its peak intensity of 50 kt at 0600 UTC 9 June. At that point, Boris’s forward speed slowed dramatically when the cyclone became caught between weak midlevel ridges to its north and south. However, upper-level easterly flow did not abate and the resultant easterly shear put an end to the intensification of the cyclone. Boris moved little on 9 June and began to weaken late in the day. On 10 June, Boris drifted to the northeast and then east while generating very little deep convection, and weakened back to a depression by 1800 UTC, when it was located about 100 n mi south-southeast of Manzanillo. With this weakening, the tropical storm watch along the Mexican coast was discontinued. The last deep convection occurred early on 11 June, and Boris degenerated to a nonconvective remnant low later that day. The remnant low then moved southeastward and dissipated on 12 June.

The ship P&O Nedlloyd Amazon (ELYL8) reported 39-kt winds and a pressure of 1003.8 mb at 2100 UTC 9 June, when it was located about 75 n mi north of Boris’s center. No tropical storm force winds were reported over land. The National Meteorological Service of Mexico reported maximum storm total rainfalls for the period 8–11 June from the following states: Michoacan 163.4 mm, Jalisco 130.2 mm, Guerrero 118 mm, and Colima 98.1 mm. Specific observation sites were not provided, so it is uncertain whether all these rains can be attributed to the tropical cyclone.

There were media reports that several homes along the Mexican coast were damaged due to heavy rains from Boris, although the precise location of this damage was not given. There was also a report of damage to homes in the town of Tequila in western Jalisco due to heavy rainfall, but satellite images suggest that these rains were not likely associated with the tropical cyclone. There are no known reports of casualties associated with Boris.

c. Tropical Storm Cristina, 9–16 July

Cristina originated from an area of disturbed weather that was first identified near Panama on 6 July. Although

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1 Watches and warnings for Mexico are issued by the government of Mexico in consultation with the National Hurricane Center.
this weather system moved westward in the manner of a tropical wave, there was no prior continuity with any identifiable waves in the Atlantic basin. The first signs of a low-level circulation center appeared on 8 July about 300 n mi south of Puerto Angel, Mexico. The system became a tropical depression on the morning of 9 July about 300 n mi south of Acapulco.

Under the influence of a midlevel ridge to its north, the depression moved just north of due west at 10–15 kt for the next 3 days. During this period, a hostile environment of strong vertical shear frequently disrupted the deep convection, causing the partial exposure of the low-level circulation center, and at times the system may not have had a well-defined center. Despite the apparently unfavorable conditions, the depression became a tropical storm on 12 July when deep convection, along with some banding features, developed near an estimated center of circulation. Cristina’s forward speed slowed and the cyclone began a turn toward the north-northwest when an upper-level low over Baja California began digging southward. Cristina slowly strengthened and reached its peak intensity of 55 kt on 14 July. Shortly thereafter, Cristina quickly weakened when its low-level center became fully exposed. The weakened tropical cyclone turned to the west-northwest in response to the lower-level steering flow. By 16 July, Cristina had degenerated to a nonconvective remnant low moving westward over colder water about 750 n mi west-southwest of the southern tip of Baja California.

d. Hurricane Douglas, 20–26 July

A tropical wave crossed the west coast of Africa on 8 July. The system moved unevenly across the tropical Atlantic until it approached the Caribbean Sea on 13 July, when the associated cloudiness and showers increased. Upper-tropospheric westerlies inhibited tropical cyclone development while the system continued westward across the Caribbean. The wave crossed Central America on 16 July, and 2 days later the associated deep convection showed enough organization to prompt a Dvorak satellite classification, as the system was moving westward to the south of Mexico. There was no significant increase in organization over the next day or so while northeasterly shear prevailed over the area, but by 20 July the vertical shear relaxed. Cloud bands associated with the wave showed increased curvature, and deep convection became more concentrated near a center located about 395 n mi south of Manzanillo. It is estimated that a tropical depression formed near that location at 1200 UTC 20 July.

After its formation, the cyclone moved northwest to north-northwestward and quickly strengthened into a tropical storm. Douglas then turned to a west-northwestward course, and by 22 July building pressures to the north of Douglas forced the system to move on a westward track. The turn to the west was accompanied by a significant strengthening episode. Douglas strengthened into a hurricane by 0000 UTC 22 July, and with a faint eye discernible in visible satellite imagery, Douglas reached its peak intensity of 90 kt by 1800 UTC that day. Such an association between westward turns and intensification has been observed in many previous tropical cyclones, and is probably a result of a deeper layer of easterly flow with low vertical shear.

On 23 July, as Douglas began to be influenced by more stable air and cooler water, the deep convection decreased in coverage and intensity and the hurricane weakened. Concurrently, microwave imagery indicated that Douglas’s inner eyewall, which had collapsed into a fragment, was replaced by an outer eyewall about 80 n mi in diameter. When Douglas began to weaken, it turned to the west-northwest and accelerated somewhat. An additional increase in forward speed occurred over the next day or two while Douglas continued to weaken. Douglas’s intensity dropped below hurricane strength by 24 July, and the cyclone weakened to a tropical depression around 0000 UTC 26 July. With a strong deep-layer ridge persisting to its north, Douglas moved westward swiftly, and decayed into a remnant low about 1025 n mi east of the Hawaiian Islands by 1800 UTC 26 July. The westward-moving remnant low lost its closed circulation soon thereafter.

e. Hurricane Elida, 23–30 July

Elida was a fast-developing hurricane that reached category 5 status on the Saffir–Simpson hurricane scale. It formed from a tropical wave that moved westward across the coast of Africa on 13 July. The wave showed little development as it moved westward across the Atlantic Ocean and Caribbean Sea, but entered the eastern North Pacific basin on 21 July and showed increasing organization the following day. A tropical depression formed from the wave on 23 July about 305 n mi south-southeast of Puerto Escondido, Mexico.

The cyclone strengthened rapidly as it moved westward. It became a tropical storm near 1200 UTC 23 July and a hurricane less than 18 h later. Elida turned west-northwestward on 24 July while continuing to deepen rapidly, and reached its peak intensity of 140 kt near 0600 UTC 25 July (Fig. 4). Microwave satellite data indicate that Elida began forming concentric eyewalls about that time, but by the time the eyewall replacement cycle was complete, the cyclone was moving over cooler waters. Elida then began to weaken.

The hurricane moved west-northwestward from 26 to 27 July and weakened to a tropical storm. A weakness in the subtropical ridge allowed the storm to turn north-northwestward on 28 July and north-northwestward the following day. Elida weakened to a depression on 29 July, and then became a nonconvective remnant low the next day. The low dissipated late on 31 July about 465 n mi west of Los Angeles, California.

While many tropical cyclones undergo periods of rapid intensification, it is very unusual for such a period to
begin while the cyclone is still a tropical depression. Elida strengthened from a 25-kt tropical depression to a 70-kt hurricane in 30 h, and then further strengthened to an intensity of 140 kt during the next 24 h. Among other recent eastern North Pacific hurricanes, only Linda of 1997 (Lawrence 1999) showed a similar evolution. That storm took 36 h to develop from 25 to 65 kt, then strengthened to 155 kt in the ensuing 24 h. It should be noted that for both Elida and Linda there were no in situ observations to verify the satellite intensity estimates, and the apparent development rate violated the constraints built into the Dvorak (1984) technique. Thus, there is considerable uncertainty regarding the exact deepening rates and peak intensity of these two storms.

The estimate of Elida’s peak intensity (140 kt) was based largely on an objective Dvorak algorithm developed by the University of Wisconsin (Velden et al. 1998), which indicated a peak intensity of 138 kt from 0300 to 0400 UTC 25 July. This technique is based in part on a comparison of infrared temperatures of the eye and the eyewall cloud tops determined from geostationary satellite data. Due to the satellite’s viewing angle and Elida’s very small eye, it is likely that the eye temperature was incorrectly measured. While such an error could result in an underestimate of Elida’s intensity, no upward adjustment to the official intensity was made due to the aforementioned Dvorak constraints.

The only ship to encounter Elida was H9LA (name unknown). It reported 36-kt winds and a 1008.5-mb pressure at 0000 UTC 24 July while located about 200 n mi from the center. This ship also provided useful data during Elida’s development into a tropical depression.

While high swells from Elida likely affected portions of the coast of Mexico, the high winds and heavy rains stayed well offshore. There were no reports of damage or casualties.

f. Hurricane Fausto, 21 August–3 September

The weather system that became Fausto was tracked from Africa nearly to Alaska. Fausto developed from a tropical wave that crossed the west African coast on 11 August and entered the eastern North Pacific basin on 17 August. By late on 18 August the system acquired enough organization to be classified using the Dvorak technique. By the following day a broad closed circulation was present, but the convective pattern had weakened. On 21 August the system began to reorganize and became a tropical depression about 400 n mi southwest of Manzanillo.

The depression initially moved westward and strengthened, becoming a tropical storm at 0000 UTC 22 August, about 450 n mi south-southwest of Manzanillo. Fausto turned to the west-northwest on a heading it would maintain for the next 6 days. It steadily strengthened, and became a hurricane later that day at 1800 UTC, when it was about 565 n mi south-southwest of Cabo San Lucas. Steady and significant strengthening continued, with Fausto reaching its peak intensity of 125 kt at 1200 UTC 24 August (Fig. 5), roughly 60 h after becoming a tropical storm. At the time of peak intensity Fausto was located about 800 n mi southwest of Cabo San Lucas.

By 0000 UTC 25 August, deep convection in the eyewall of Fausto began to diminish, and a weakening trend began, one that was nearly as steady as the intensification had been. Fausto crossed the 26°C sea surface temperature isotherm near midday on 25 August,
and became a tropical storm again by 1200 UTC the following day. Even though Fausto subsequently failed to generate any more deep convection (and therefore was arguably no longer a tropical cyclone), its large circulation was slow to spin down. Winds did not fall below tropical storm strength until 28 August, shortly after Fausto crossed 140°W longitude and entered the central Pacific basin. Fausto is considered to have become a remnant low by 1200 UTC 28 August.

The remnant low of Fausto continued on a westward track, passing about 430 n mi north of the Hawaiian Islands on 30 August. During the day the surface circulation passed underneath an upper-level low and redeveloped deep convection. With the redevelopment of convection Fausto became a tropical depression again, although it did have some subtropical characteristics; QuikSCAT scatterometer passes and conventional satellite imagery indicated that the strongest winds and convection were located more than 120 n mi east of the center. Fausto moved to the west-northwest on 31 August, and during the day the upper-level flow over the center gradually changed from cyclonic to anticyclonic. (A scatterometer pass at 1642 UTC 1 September indicated that the surface wind field was contracting as the upper-level anticyclonic flow developed.) Fausto strengthened and became a tropical storm later on 1 September. On 2 September, Fausto turned north and accelerated ahead of a midlatitude frontal system, becoming absorbed by an extratropical low shortly after 0000 UTC the next day.

The ship Jo Lonn (PFEW) reported 35-kt winds at 0000 UTC 24 August and again at 0000 UTC 25 August. There were no reports of damage or casualties associated with Fausto.

**g. Tropical Storm Genevieve, 26 August–1 September**

A tropical wave that crossed Dakar, Senegal, on 13 August was the precursor disturbance to Genevieve. As the wave moved westward it lost most of its associated convection, and it was not until the system was south of Hispaniola on 19 August that the thunderstorm activity partially regenerated. Thereafter, the wave continued westward with a gradual increase in organization and crossed Central America. A tropical depression formed on 26 August about 500 n mi south of Cabo San Lucas, and the depression became a tropical storm one day later. Genevieve was approaching hurricane strength, with maximum winds of 60 kt and a minimum pressure of 989 mb at 0000 UTC 28 August, when it turned to the northwest over cooler waters and its convection began to diminish. Genevieve degenerated to a nonconvective remnant low about 960 n mi west-northwest of the southern tip of Baja California on 1 September. There were no reports of damage or casualties.

**h. Hurricane Hernan, 30 August–6 September**

Hernan was the second of the season’s three category 5 hurricanes. It developed from a disturbance in the intertropical convergence zone that appears to be related to a weak tropical wave that crossed the African coast on 16 August. The disturbance became a tropical cyclone on 30 August when a closed circulation and organized convection developed about 340 n mi southeast of Manzanillo.

Hernan (Fig. 6) had an uncomplicated life cycle. It moved along the southwest periphery of the subtropical high pressure ridge centered over Mexico, taking a west-
northwestward track for 5 days and moving northwestward thereafter until dissipation. After genesis, the cyclone strengthened steadily, with maximum winds reaching 140 kt at 1200 UTC 1 September. The center of Hernan passed about 90 n mi to the south of Socorro Island when the intensity was near its maximum value. No reports were received from the island regarding conditions experienced there. Hernan’s intensification of 110 kt in 54 h nearly matched the 115-kt intensification of Elida over a similar interval.

Decay followed, induced by cooler waters under the cyclone, in which the winds decreased to 30 kt over a period of 96 h. On 4 September, increasing vertical shear reinforced the weakening process, and by 6 September Hernan was devoid of significant convection, degenerating to a remnant low about 780 n mi west of Cabo San Lucas. The remnant low drifted southwestward until it dissipated on 9 September.

On 31 August, two ships (the Eemsgracht and the Zim Europa) in the northeast quadrant of the cyclone reported 37- and 36-kt winds, respectively.

i. Tropical Storm Iselle, 15–20 September

The tropical wave that spawned Iselle crossed the west coast of Africa on 31 August, accompanied by well-organized deep convection. However, convection gradually weakened while the system moved westward. The northern portion of the wave separated and developed into Tropical Depression Seven in the Atlantic basin on 7 September, while southwestward vertical wind shear prevented development of the southern portion. The wave remnant continued to move rapidly westward across the tropical Atlantic Ocean and northern South America, and emerged into the eastern North Pacific basin on 10 September.

On 13 September the wave encountered strong low-level southwesterly flow and the forward speed of the system slowed. Convection then began to become organized around a developing low-level cyclonic circulation. By 15 September, a well-defined upper-level outflow became established and the system became a tropical depression about 270 n mi south of Manzanillo.

The depression moved west-northwestward and strengthened into a tropical storm at 0000 UTC 16 September, about 250 n mi southwest of Manzanillo. A tropical storm warning was briefly in effect, from 0000 until 0900 UTC 16 September for southwestern Mexico from Lázaro Cardenas to Puerto Vallarta, while Iselle moved parallel to the coastline. Iselle continued northwestward for the next 3 days. During that time, Iselle gradually strengthened and eventually reached a peak intensity of 60 kt late on 17 September about 360 n mi west-southwest of Cabo San Lucas.

Shortly after reaching its peak intensity, Iselle made a sharp turn to the northeast in response to the mid- to upper-level flow ahead of a deep midlatitude trough. Vertical shear also increased and Iselle rapidly weakened, becoming a tropical depression on 19 September about 80 n mi southwest of Puerto Cortes, Mexico. Early on 20 September, Iselle degenerated into a nonconvective low. The circulation dissipated later that day about 60 n mi southwest of Puerto Cortes.

Iselle’s effects on land were relatively small. A sustained wind of 40 kt was observed in Manzanillo at 2300 UTC 15 September. Iselle briefly produced locally heavy rainfall across the southern third of the Baja California peninsula on 19 September, but rainfall totals...
j. Tropical Storm Julio, 25–26 September

Tropical Storm Julio, one of two landfalling tropical cyclones in 2002, formed from a persistent area of disturbed weather near the west coast of Mexico. As the large circulation of Atlantic Hurricane Isidore approached the Yucatan Peninsula of Mexico, an area of westerly surface winds and convection developed on 21 September from 10°–17°N between 90°–107°W. Convective activity generally increased over the next 2 days there, and a poorly defined low-level circulation developed late on 23 September. The system gradually became better organized, and became a tropical depression by 0000 UTC 25 September about 175 n mi southwest of Acapulco. The depression moved northward and strengthened. It became a tropical storm near 1200 UTC that day (Fig. 7), and 3 h later a tropical storm warning was issued for the coast of Mexico from Zihuatanejo to Punta San Telmo. A tropical storm watch was also issued west of Punta San Telmo to Manzanillo. Julio reached its maximum intensity of 40 kt prior to landfall on the Mexican coast just west-northwest of Lazaro Cardenas around 0000 UTC 26 September. A subsequent northwestward motion took the center over the mountains of southwestern Mexico, where the system dissipated north of Manzanillo later that day. The warnings and watches were discontinued at 0900 UTC 26 September when Julio weakened over land.

Julio caused locally heavy rains and gusty winds over portions of the southern coast of Mexico, and there were media reports of damage to homes from flash flooding. There were no reports of casualties. A sustained wind of 35 kt, with a gust to 45 kt, was observed in Zihuatanejo at 2042 UTC 25 September, as was a minimum pressure of 1002.3 mb from 1745–2042 UTC.

k. Hurricane Kenna, 22–26 October

After reaching a peak intensity of 145 kt, Hurricane Kenna made landfall near the fishing village of San Blas, Mexico, as a category 4 hurricane with winds estimated to be 120 kt. Only an unnamed hurricane in 1959 and Madeline in 1976 were stronger than Kenna at the time of landfall. The hurricane was responsible for four deaths.

1) SYNOPTIC HISTORY

Kenna developed from a disturbance that moved westward across Central America and entered the eastern North Pacific basin on 19 October. Using satellite Hovmöller diagrams, it is possible to track the disturbance back to about 70°W on 16 October, and the disturbance may have been associated with a tropical wave that passed Barbados late on 14 October. After crossing Central America, the disturbance gradually became better organized, and Dvorak classifications began late on 20 October. The system continued to develop, and became a tropical depression at 0000 UTC 22 October about 325 n mi south of Acapulco, Mexico.

The depression moved westward and quickly reached tropical storm strength at 0600 UTC 22 October. Kenna, moving around the periphery of midlevel high pressure over Mexico, turned to the west-northwest with little change in strength for the next 18 h. During this time,
much of Kenna’s deep convection was associated with rainbands well removed from the circulation center, but on 23 October, the cyclone strengthened when these bands began to dissipate and convection became concentrated closer to the center. Kenna became a hurricane about 400 n mi south of Cabo Corrientes, Mexico, between 1200 and 1800 UTC 23 October. Kenna continued to strengthen on 24 October, while its heading turned to the northwest and then north late in the day and its forward speed slowed to about 9 kt. At 1800 UTC 24 October, roughly 24 h after reaching hurricane strength, reports from a reconnaissance aircraft indicated that Kenna’s winds had reached 140 kt and its minimum pressure had fallen to 917 mb. The cyclone’s intensification of 110 kt in 54 h was similar to that of Elida and Hernan, the season’s two previous category 5 hurricanes.

The flow ahead of a large mid- to upper-level trough west of Baja California turned Kenna to the northeast beginning late on 24 October. As the hurricane began to accelerate toward the coast of Mexico, satellite imagery suggests that Kenna intensified slightly and reached its peak intensity of 145 kt with a minimum pressure of 913 mb near 0000 UTC 25 October. At this time Kenna (Fig. 8) was about 125 n mi west-southwest of Cabo Corrientes. Kenna continued to accelerate, and although the hurricane was still over warm waters, it began to weaken under increasing shear associated with the upper trough. By 1200 UTC that day, a second reconnaissance aircraft reported that the minimum pressure had risen to near 940 mb. Despite the sharp increase in pressure, convective activity increased in the hours just prior to landfall, and cloud-top temperatures dropped to \(-89^\circ\text{C}\). The reconnaissance aircraft reported extremely severe turbulence that was among the most intense ever experienced by the flight crew. Data from the aircraft indicated that the hurricane’s maximum winds were only slowly decreasing, and Kenna made landfall near San Blas, Mexico, at 1630 UTC, with winds estimated to be near 120 kt. Kenna continued moving northeastward and weakened very rapidly inland over the mountains of Mexico; by 0000 UTC 26 October it was a minimal tropical storm, and the circulation dissipated by 0600 UTC. The remnants of the tropical cyclone moved into the northwestern Gulf of Mexico later that day, and enhanced rainfall in the southeastern United States.

2) Meteorological statistics

On several occasions, the reconnaissance aircraft reported 700-mb flight-level winds of about 145 kt, corresponding to a surface wind of about 130 kt. A dropsonde at 1857 UTC 24 October reported average winds of 180 kt over the layer from 75 to 225 m (the lowest 150 m of wind data available). Adjustment of this observation to the surface (Franklin et al. 2003) yields a surface estimate of 140 kt, and this was the basis for the assigned best-track maximum wind near the time of the reconnaissance mission. The peak intensity of 145 kt is based on an increase in both subjective and objective Dvorak T-numbers in the hours after the aircraft mission concluded. While the Dvorak classifications were highest at 0600 UTC 25 October, a sequence of satellite microwave passes shows that the eyewall began

\footnote{This dropsonde also reported a wind of 192 kt at an elevation of 116 m. This is the highest wind speed recorded by a dropsonde in a hurricane.}
to decay after 0111 UTC. As a result, the peak intensity of Kenna has been assigned to 0000 UTC 25 October.

The lowest observed pressure in Kenna was 918 mb at 1859 UTC 24 October. However, the dropsondes released in the eye of Kenna tended to miss the pressure center, as the surface winds on these drops were near 30 kt. Therefore, minimum pressures in the best track are slightly lower than the raw values reported in aircraft vortex messages. Kenna’s minimum pressure is estimated to be 913 mb, based again on an increase in Dvorak classification numbers after the time of the aircraft mission.

The reconnaissance mission on 25 October provided some interesting observations. The highest satellite-based intensity estimates occurred at 0600 UTC, when the minimum pressure is estimated to have been 915 mb. After 0600 UTC, the eye rapidly disappeared. At 1335 UTC, the aircraft reported a minimum pressure of 945 mb, 27 mb higher than what had been observed 17 h previously, yet the peak 700-mb flight-level winds (147 kt) were virtually unchanged. As noted earlier, there was a burst of very deep convection in the early morning hours just prior to landfall, with cloud-top temperatures near −89°C. The conflicting signals from the pressure and wind data make it difficult to assign a landfall intensity. The best track landfall intensity of 120 kt is a compromise of the various observations, including a rapid deterioration in the overall satellite presentation despite the deep cold convection, and reflects a concern that the aircraft wind report may not have been completely representative of surface conditions. One could easily argue for a landfall intensity either 10 kt higher or lower than the value given here.

There were very few surface observations from the landfall of Kenna. At Tepic, Nayarit, (located about 15 n mi inland) the peak measured wind (10-min mean) was 76 kt, with a storm total rainfall of 85 mm. At Islas Marias, about 40 n mi to the left of the track of Kenna, 35 mm of rain was recorded. The maximum rain totals reported from the states of Colima and Nayarit were 250 and 120 mm, respectively. There were no ship reports of winds of tropical storm force associated with Kenna.

The Meteorological Service of Mexico estimates that the storm surge in San Blas was as high as 16 ft (5 m). Storm surge also affected Puerto Vallarta, but no measurements are available. There were reports of 10-ft waves rushing inland from the bay.

### 3) Casualty and Damage Statistics

Reports indicate that Kenna was responsible for four deaths. In San Blas, an elderly woman died when the wall of her house collapsed. One person in Santiago Escuintla was killed by flying debris. There were two deaths due to drowning. An elderly man drowned in Santiago Escuintla and another elderly man fell into the river Florido. Both of these are believed to have occurred during the storm while the victims fled their homes. All but roughly 200 or so of the 9000 residents of San Blas evacuated the village, likely accounting for the relatively low number of casualties. There were media reports of over 100 injuries in San Blas and Puerto Vallarta from flying glass and other debris.

In Puerto Vallarta, storm surge was primarily responsible for the estimated $5 million (U.S. currency) of damage, largely to hotels. There are no monetary estimates of damage in San Blas; however, media reports indicate that 80%–90% of the homes were damaged or destroyed. Large commercial shrimp boats were pushed up to 300 yd from their docks.

### 4) Warnings

A hurricane watch was issued at 0900 UTC 24 October for the Mexican coast from Mazatlan to Cabo Corrientes. A tropical storm watch was issued at the same time from Cabo Corrientes to Manzanillo. A hurricane warning was issued for the coastline from Mazatlan to La Fortuna at 1500 UTC 24 October, roughly 25 h prior to landfall.

#### 1. Tropical Storm Lowell, 22–31 October 2002

Lowell originated from a westward-moving disturbance that crossed Central America and entered the eastern North Pacific basin on 12 October. There was some increase in convection associated with the disturbance on 18 October as it neared 120°W longitude, but it was not until 22 October that the system acquired both a broad circulation and enough organized convection to become a tropical depression about 1380 n mi southwest of Cabo San Lucas. After briefly drifting north, the depression turned to the west and strengthened to a tropical storm with winds of 40 kt the following day. At that point southwesterly vertical wind shear began to disrupt the convective pattern, and Lowell weakened back to a depression on 24 October. Lowell crossed 140°W longitude and entered the central Pacific hurricane basin on 26 October. On 27 October, Lowell regained tropical storm strength as the vertical wind shear lessened. Lowell reached its peak intensity of 45 kt on 28 October about 700 n mi east-south-east of the Hawaiian Islands. Lowell then turned to the west-southwest and began to weaken, becoming a tropical depression again on 29 October, and dissipating 2 days later about 600 n mi southeast of Hawaii.

#### 3. Nondeveloping tropical depressions

Tropical Depression Three-E developed from a tropical wave that emerged from the west coast of Africa on 12 June. Nearly 2 weeks later on 27 June, a depression formed from the wave about 970 n mi south-west of Cabo San Lucas. The depression moved westward and changed little in organization during the following 2 days, and weakened on 29 June when strong
vertical wind shear separated the low-level center from the thunderstorm activity. The nonconvective remnant low continued moving westward for a few more days.

Tropical Depression Seven-E formed from a tropical wave that crossed the coast of Africa on 23 July and reached the eastern Pacific on 29 July. The wave continued westward with little development until 3 August, when convective activity started to increase. The system became a tropical depression on 6 August about 785 n mi southwest of Cabo San Lucas. Development was then halted by southwesterly vertical wind shear. The cyclone moved northwestward for 2 days before it dissipated early on 8 August about 930 n mi west-southwest of Cabo San Lucas.

Tropical Depression Eleven-E formed about 250 n mi south-southeast of Cabo San Lucas on 5 September. It moved northwestward and threatened southern Baja California on 6 September, and then moved slowly and erratically while weakening on the following day. It then turned northward and dissipated about 225 n mi west-southwest of Cabo San Lucas on 8 September.

Tropical Depression Sixteen-E was first identified on 11 November as a disturbance in the intertropical convergence zone, a few hundred miles south of Acapulco. Moving northwestward, and despite strong westerlies aloft, the system developed a well-defined circulation center and became a tropical depression on 14 November, while located 470 n mi south of Cabo San Lucas. Later that day the low-level center became exposed and the depression turned west-southwestward. There were occasional bursts of convection for the next day or so, but the depression degenerated into a remnant low on 16 November about 630 n mi southwest of Cabo San Lucas.

### 4. Forecast verifications

For all operationally designated tropical cyclones in the eastern North Pacific basin, the NHC issues an “official” forecast of the cyclone’s center position and maximum 1-min surface wind speed. These forecasts are issued every 6 h, and each contains projections valid 12, 24, 36, 48, and 72 h after the nominal (synoptic)
Fig. 9. Official track forecasts (dashed lines, with 0-, 12-, 24-, 36-, 48-, and 72-h positions indicated by open circles) for Hurricane Kenna. Kenna’s best track is given by the thick solid line with positions given at 6-h intervals.

Fig. 10. Official intensity forecasts (dashed lines) for Hurricane Kenna. The best-track intensity is given by the thick solid line.

forecast time. At the conclusion of the season, the forecasts are evaluated by comparing the forecast positions and intensities to the corresponding post-storm-derived best track positions and intensities for each cyclone. Forecasts are included only if the system was a tropical or subtropical cyclone at both the forecast and the verifying time; extratropical and remnant low stages are excluded. The current verification procedures differ from those used in previous years, in which the depression stage was also excluded from the verification.

Track forecast error is defined as the great-circle distance between a cyclone’s forecast position and the best track position at the forecast verification time. Table 2 presents the results of the NHC official track forecast verification for the 2002 season, along with results averaged for the 10-yr period 1992–2001. To assess the
degree of skill in a set of forecasts, the forecast error can be compared with the error from CLIPER, a climatology and persistence model that represents a “no skill” baseline level of accuracy (Neumann 1972). It is seen from the table that mean official track forecast errors were smaller in 2002 than for the previous 10-yr period (by amounts ranging from 7% at 12 h to 30% at 72 h). Not only were the forecasts more accurate in 2002 than they were over the previous decade, but the forecasts were also more skillful; a comparison of forecast errors relative to CLIPER for the 2002 season with those from the longer period shows, in fact, that forecast skill in 2002 was about 2 to 3 times higher than the mean over the preceding decade. Forecast skill was also somewhat higher in 2002 than it was in 2001 (Avila et al. 2003). Improvements in the official forecasts are attributed primarily to global numerical forecast models, which have improved significantly in recent years.

Forecast intensity error is the absolute value of the difference between the forecast and best track intensity at the forecast verifying time, that is, this statistic does not consider the forecast bias. Table 3 presents the results of the NHC official intensity forecast verification for the 2002 season, along with results averaged for the 10-yr period 1992–2001. To assess the degree of skill in a set of intensity forecasts, the forecast error can be compared with the error from the Statistical Hurricane Intensity Forecast model (SHIFOR; Jarvinen and Neumann 1979), the climatology and persistence model for intensity that is analogous to the CLIPER model for track. The table shows that mean intensity errors in 2002 were mostly a little bit larger than their previous 10-yr means. SHIFOR forecast errors in 2002 were also mostly larger than their previous 10-yr means, which suggests that this year’s storms were somewhat more difficult than normal to forecast. Forecast skill in 2002 was slightly higher than in 2001 (Avila et al. 2003).

Hurricane Kenna provides a good illustration of the progress that has been made in forecasting the tracks of tropical cyclones and the relative lack of progress that has been made in forecasting their intensities. Figure 9 shows the official track forecasts for Kenna and Fig. 10 shows the official intensity forecasts. Note the very strong clustering of the forecast tracks very close to Kenna’s landfall location. These accurate track forecasts were based largely on a consensus of global numerical models, such as the National Centers for Environmental Prediction’s Global Forecast System (formerly known as the Aviation model; Kanamitsu et al. 1991), the Geophysical Fluid Dynamics Laboratory (GFDL) model (Kurihara et al. 1998), the Navy Operational Global Atmospheric Prediction System (NOGAPS; Goerss and Jeffries 1994), and the United Kingdom Met Office Model (UKMET; Heming and Greed 2002). On the other hand, Kenna’s rapid strengthening, from 40 to 140 kt in 42 h, was not anticipated. Underforecasts of such episodes are common, and reflect the fact that the best guidance model for intensity prediction, the Statistical Hurricane Intensity Prediction Scheme (SHIPS; DeMaria and Kaplan 1999), is a statistical–dynamical model that is virtually incapable of forecasting extreme events.

Acknowledgments. The authors would like to thank Chris Velden and David Stettner of the University of Wisconsin/Cooperative Institute for Meteorological Satellite Studies (CIMSS) for the satellite imagery presented here. Tropical Prediction Center colleague Dr. Stephen R. Baig produced the track charts.

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