NOAA Technical Memorandum NWS WR-[redacted] 159

TROPICAL CYCLONE EFFECTS ON CALIFORNIA

Salt Lake City, Utah
October 1980

U.S. DEPARTMENT OF COMMERCE / National Oceanic and Atmospheric Administration / National Weather Service

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TROPICAL CYCLONE EFFECTS ON CALIFORNIA

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October 1980

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DEPARTMENT OF COMMERCE
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NATIONAL OCEANIC AND
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TROPICAL CYCLONE EFFECTS ON CALIFORNIA

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ABSTRACT. Each decade, about one-hundred fifty cyclones form off the southwest coast of Mexico or regenerate there from Caribbean storms that have crossed Central America; about half of them become full hurricanes. Five or six cyclones per decade actually reach California or Arizona, either as weak circulations or most commonly as masses of warm, moist, unstable air which cause heavy rains in August and September.

Although such storms were recognized and charted by Redfield in 1855, their existence was denied officially until after 1920, when increased ship traffic west of Mexico provided many detailed reports. Tracks of 40 tropical cyclones affecting California and Arizona since 1904, identified through comparison of various official publications, are given, together with summaries of damage from rain, wind, and waves.

I. INTRODUCTION

Tropical cylcones have a much larger effect on the climate of the southwestern United States than is realized by many people, including some meteorologists and climatologists. The growing awareness of the consequences to southwestern United States, especially California, of storms from the south will be traced in this discussion, with accounts of more than thirty tropical cyclones that have affected southern California from 1906 to 1978.

A century ago any suggestion that tropical cyclones could affect California's climate would have been ridiculed. Then, and for several decades thereafter, the official position of the U. S. Weather Bureau was that:

> "The occurrence of tropical storms is confined to the summer and autumn months of the respective hemispheres and to the western parts of the several oceans". (Hydrographic Office, 1910.)

Likewise, an authoritative Weather Bureau bulletin on West Indian Hurricanes (Fassig, 1913) did not include the northeast Pacific among the five world regions where such storms occur.

This official denial of the existence of tropical cyclones in the eastern north Pacific ignored the pioneering work of William C. Redfield (1789-1857) who had extended his studies of the rotary character of storms to "establish the prevalence of violent cyclones upon the southwestern coast of North America in all seasons of the year" by plotting the tracks of five tropical cyclones from June to October 1850 and one in each of the three following years (Redfield, 1854). In analyzing the typhoons encountered by Commodore M. C. Perry's expedition to Japan, 1852-53, Redfield (1856, 1857) added four more tropical cyclones to his map of such storms from Africa to China (Figure 1). Later copies of this map of "Gales and Hurricanes" dropped the first word and hence suggested winter hurricanes on the Oregon coast. Also active in cataloging tropical storms off Mexico's west coast was the Deutsche Seewarte (1897) which listed 45 storms, 1832-1892.

A tropical cyclone was suggested by Abbe (1895) as the probable cause of unusual waves in November 1895 at the tide gage at Sausalito, across the Golden Gate from San Francisco. He drew on Redfield's work to report that:

> "...between the Sandwich Islands the coast of Mexico, hurricanes of considerable violence occasionally occur... The number of incipient cyclones, typhoons or hurricanes is apparently quite large and uniformly distributed in a zone across the breadth of the Pacific between N. 5° and 15°, but the proportion of those that die out before becoming important hurricanes appears to increase as we approach the Mexican coast".

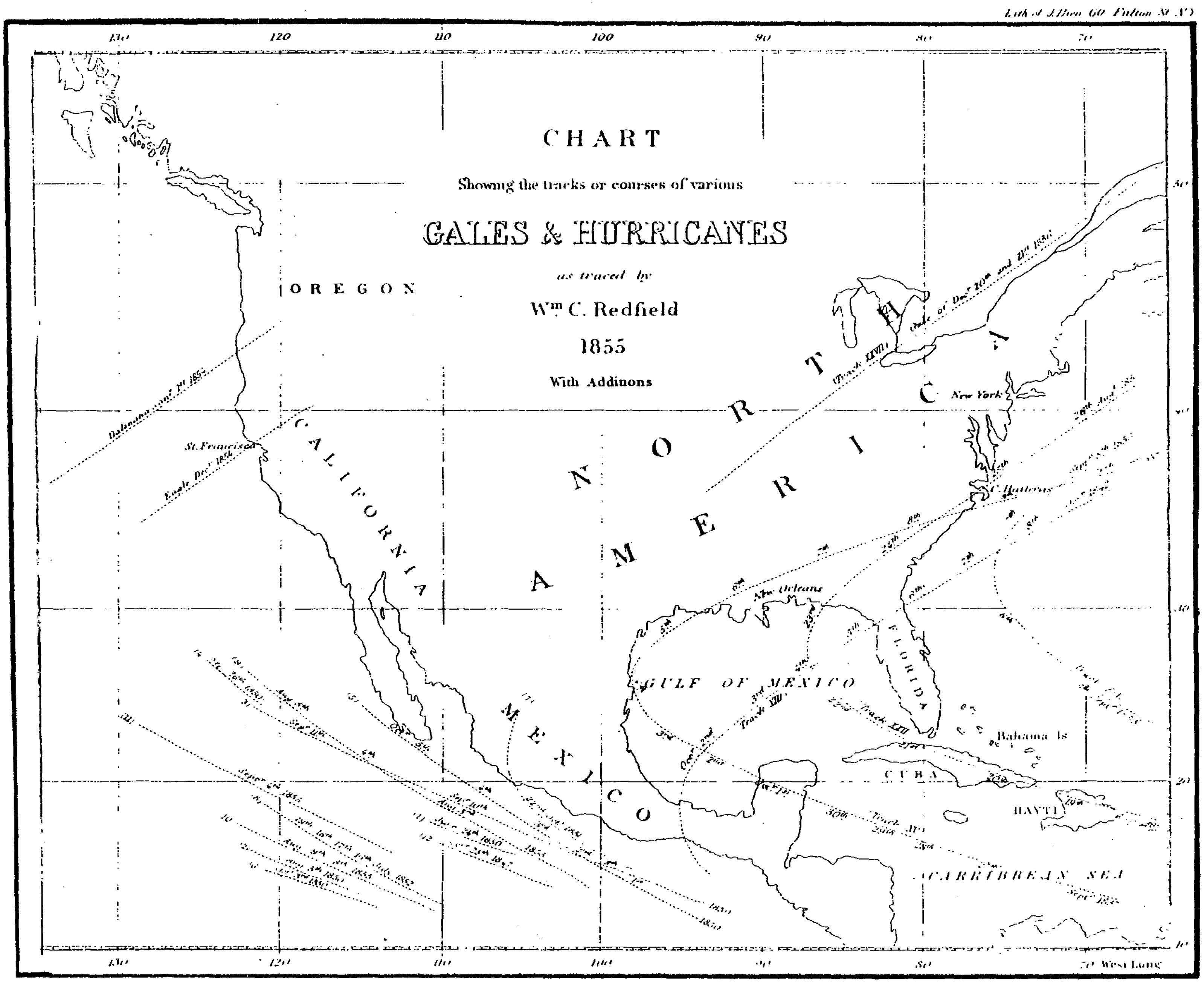

Figure 1. "Chart showing the tracks or courses of various GALES and HURRICANES as traced by Wm. C. Redfield, 1855, with additions." (From Redfield, Am. J. Sci. and Arts, 24:21-38, 1857.)

"Probably the earliest records of Mexican west-coast hurricanes are those to be inferred from the non-arrival of the annual Manila Galleon, and from the fragmentary reports of 'tempestades' to be found" in various mission and military reports and letters during the three centuries of Spanish rule, Ives (1949) wrote. One such account indicates that by 1730 "hurricane behavior was known, and at least partly understood".

Mexican west coast residents spoke of the chubasco, a heavy coastal squall usually associated with a violent thunderstorm which in turn may have resulted from a passing tropical cyclone. They called the most violent coastal storms:

> "El Cordonazo de San Francisco--the Lash of St. Francis--due to a popular conception that they most often occur at the time of the feast of St. Francis on October 4th... The term is generally used for the southeastern and southwesterly winds along the coast associated with a tropical cyclone a short distance at sea". (Kalstrom, 1952, p.99.)

In southern California and adjacent Baja California and Arizona, a Sonora storm was a period of a day to a week in late summer or early autumn with widespread showers and thunderstorms in air from the Sea of Cortez or possibly the west coast of Baja California (Blake, 1923).

Despite widespread local recognition of the effects of tropical cyclones in the eastern north Pacific and documentation of such storms by Redfield (1854, 1857), a quarter-century later Greely (1888), Chief of the Signal Corps, in his popular book discussed "violent low-area storms" of our tropical areas not including the northeast Pacific. Davis (1894, pp. 191-192) did not include the northeast Pacific as one of the "five regions in which tropical cyclones appear with characteristic regularity" but mentioned:

> "Certain cyclones that have been traced for a relatively short distance along a northwest course...west of Central America...".

His successor textbook (Milham, 1911, 1925 p. 274) accepted the Weather Bureau dictum: "The tropical cyclones always occur on the west side of an ocean". He did not mention those west of Mexico.

II. OBSERVATIONS

Development of a tropical cyclone, the general term for a rotating storm in the tropics, occurs in three stages: tropical depression, with (1-minute average) winds up to 33 knots; tropical storm, with winds from 34 to 63 knots; and hurricane (in the Atlantic and eastern Pacific Oceans), typhoon (western Pacific), or just cyclone (south Pacific and Indian Oceans) with winds of 64 knots and more up to perhaps 200 knots (Neumann et al. 1978). In effect, the divisions are at 38 mph = 17 m/s and 73 mph = 32 m/s. Formerly, slightly different definitions were used internationally: 36 kn = 40 mph = 18 m/s and 64 kn = 74 mph = 32 m/s.

Tropical cyclones form over warm water 8 degrees or more from the equator--far enough poleward for the Coriolis effect to impart rotation. They have warm cores without appreciable variations in temperature or moisture content in any portion; in contrast, extratropical cyclones have cold cores and involve density contrasts between warm and cool air.

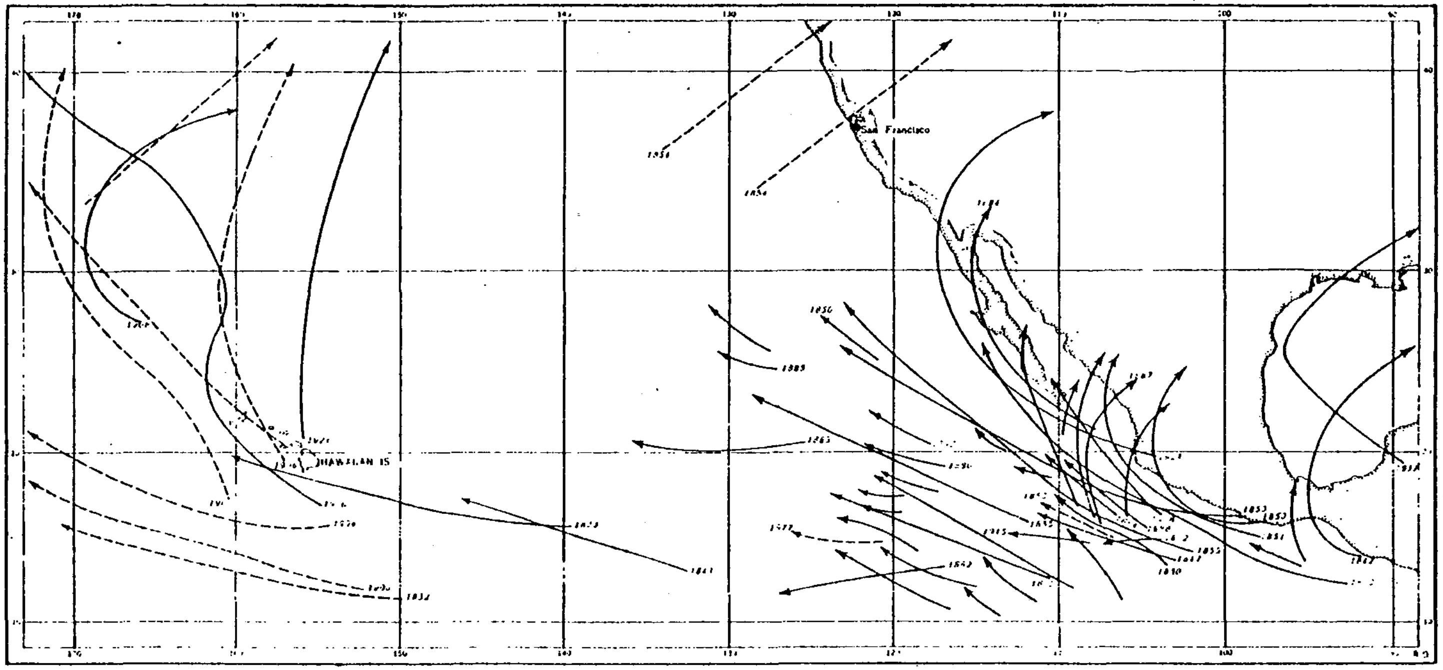

Figure 2. Approximate tracks of about 60 tropical storms, eastern Pacific Ocean, 1840-1922. (From Visher, Mon. Wea. Rev. 50:296-297, June 1922.)

Tropical cyclones derive their energy from the release of latent heat of condensation, while extratropical cyclones are driven primarily by release of potential energy of thermal differences. Since 1972, hybrid subtropical cyclones have been recognized. They have cold cores but no fronts or density differences; some may become tropical cyclones.

Few, if any, eastern Pacific cyclones retain their intensity and thence their devastating winds north of the 30th parallel. Instead, they are noted for and identified by the extensive rains that precede and accompany the dying center. A decade ago Harris (1969) found that one fourth of the annual rainfall of the Colorado desert of southeastern California was derived from tropical cyclones. In many cases, all that remained was a flow of warm, moist air enough to bring extensive rains to the deserts and especially the surrounding mountains.

Before 1970, the Gulf of Mexico was generally assumed to be the ultimate source of the summer showers east of the Sierra Nevada and the coastal ranges of southern California. But some students had doubts, and Hales (1972, 1974), Brenner (1973), and Hansen (1975) demonstrated that most summer moisture traveled northward up the Sea of Cortez (Gulf of California), rather than surmounting the continental divide in which the lowest pass is more than 1 km above sea level. Hales spoke of "surges" of moist air up the Sea of Cortez, consequences of either tropical cyclones or easterly waves. A more descriptive and possibly more appropriate name for these moisture pulses, of several days' duration, might be "El Respiro de Cortez" the exhalation (breath) of Cortez.

III. RECOGNITION

Changing patterns of maritime commerce and technological advances caused tropical cyclones of the eastern north Pacific to be reported with increasing frequency. The number of ships in Baja California waters increased a hundred-fold after annexation of California to the United States and discovery of gold there, both in 1848. Opening of the Panama Canal in 1914 brought shipping much closer to the coast than the former routes from Cape Horn to California and the Orient.

One such trip encountered a storm "of moderate violence" which had "prevailed on September 4-5, 1915, about 500 miles south of the most southerly point of Lower California", Kimball (1915) said in the first published report (since Redfield's) of such storms. These, he said, were too infrequent "to warrant tracing on the Pilot Charts", although "in recent times a few disturbances... have had their inception somewhat to the east of the Hawaiian Islands" and "future observations may show that a storm track crosses the Pacific from Mexico to Japan". More cyclones were reported and by 1923 a further reprinting of the "Cyclonic Storms" account on the backs of Pilot Charts had been revised to read:

> "...the occurrence of Tropical Cyclones is confined, for the most part, to the western portion of the several oceans... Small but nevertheless violent cyclones occur in the eastern part of the North Pacific Ocean, off the coast of Mexico and Central America".

During the 1920s, vital information on the tropical cyclones of the eastern north Pacific Ocean resulted from increased ship reports (thanks to expanded radio services), larger surface weather networks in the United States and Mexico, and especially the labors of two diligent investigators: Stephen Sargeant Visher (1887-1967), professor of geography at the University of

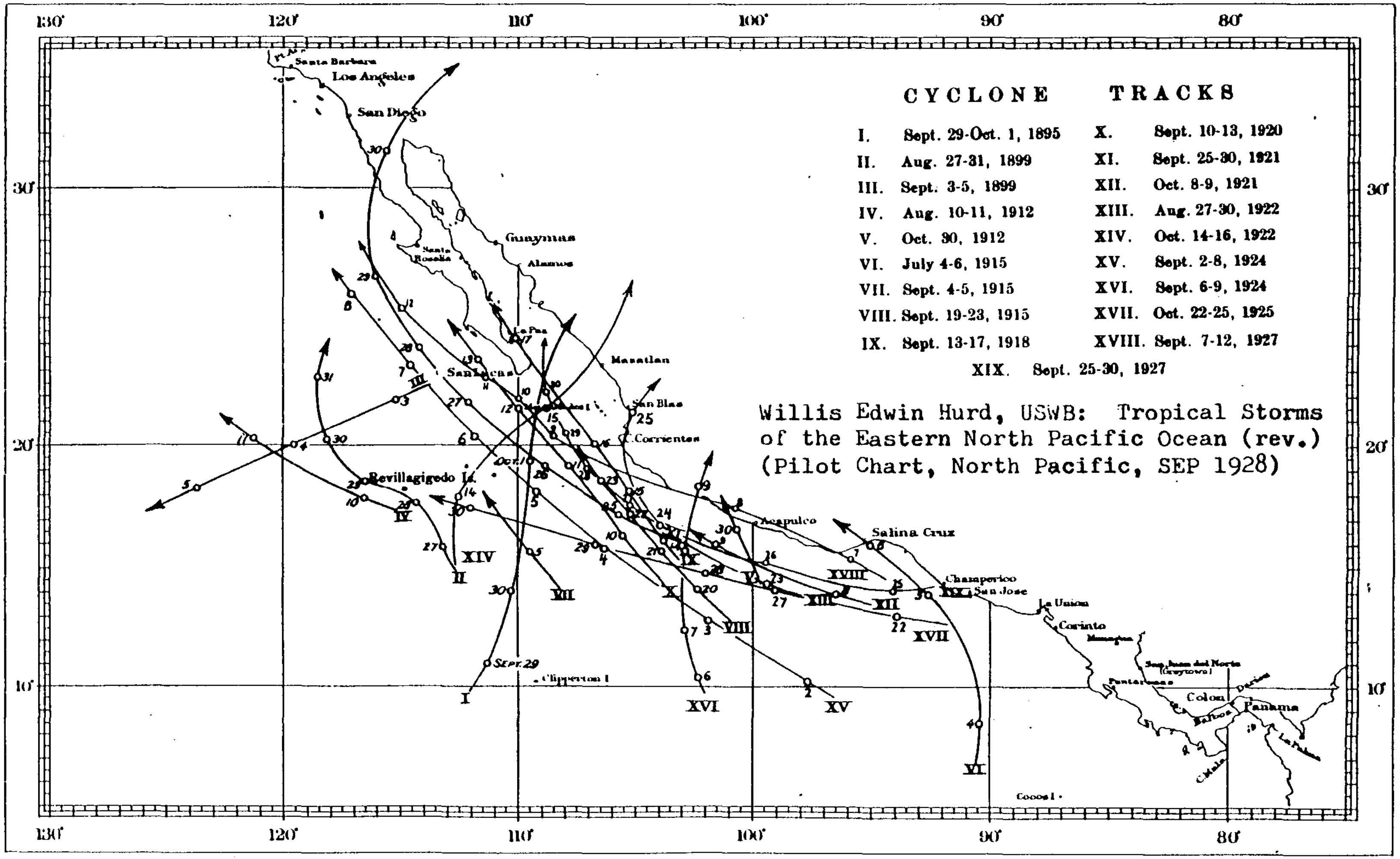

Figure 3. Cyclone tracks off west coast of Mexico, 1895-1927. (From Hurd, North Pacific pilot chart, September 1928.)

Indiana 1919-1958, and Willis Edwin Hurd (1875-1963?), marine climatologist in the Weather Bureau 1910-1944.

As a Fellow of the Bernice Bishop Museum of Honolulu (1921-22) and with assistance from his university, Visher covered the Pacific Ocean to collect data and to confer with forecasters for several weeks each in Honolulu, Tokyo and Kobe, Shanghai, Manila, Brisbane and Melbourne, Auckland and Wellington, and Suva. His resulting monograph (Visher, 1925) and shorter papers (Visher, 1922, 1923, 1930) began to reveal the true extent of tropical storms in the Pacific and Indian Oceans (Figure 2).

Hurd's description of a few east Pacific tropical cyclones in an article on the back of a Pilot Chart in 1913 was revised and expanded on later charts in 1923, 1926, and 1927, revised in 1928 (Figure 3) and republished almost annually, with updating, until a third edition appeared in 1936 and was reprinted repeatedly until 1948. For nearly two decades Hurd prepared the summary of north Pacific weather each month for the Monthly Weather Review and wrote special articles (Hurd, 1929a, 1929b). Significant papers also came from the official-in-charge of the San Diego Weather Bureau Office, Dean Blake (1923, 1933, 1935, 1937).

Until 1920, few weather observations were available from the west coast of Mexico and especially from Baja California. Thereafter the Mexican weather network expanded, and Vazquez Schiaffino (1927), Regional Director at Mazatlan, could compile annual maps, 1921-1925, of tropical cyclones affecting Mexico. But they don't always agree with representations of the same cyclones on monthly maps in the Monthly Weather Review or the maps presented in Hurd's frequent revisions or in the official catalog of Atlantic cyclones (Neumann et al. 1978).

Vazquez Schiaffino's annual maps end in 1925. Serra (1971) included those tracks, and subsequent ones, in monthly maps of "Hurricanes and Tropical Storms of the West Coast of Mexico". Both Vazquez Schiaffino (1927) and Serra (1971), as well as Lucio (1930), were concerned primarily with landfall storms, those that struck the Mexican coast and passed inland, even crossing the entire country. They made little effort to follow the storms northward into the United States or west of California.

Monthly accounts by Hurd and his successors, in the Monthly Weather Review, of Pacific tropical storms were replaced, after 1956, by reports in the Mariners Weather Log and annual summaries there and in Climatological Data, National Summary. Some of these were also reprinted on the backs of Pilot Charts, until printing consolidation, issuing three monthly maps together, eliminated most such material from them after 1976.

Among American authors only Blake (1933, 1935) and Eidemiller (1978) diligently followed cyclones onto land; the latter found that about 30% of all tropical cyclones came within 800 km of San Diego--close enough for their upper-tropospheric outflow to fling moisture against the southern California mountains and cause late summer and early autumn rains. The other students and tabulators, including forecast offices in Honolulu and San Francisco, stopped tracking cyclones when winds dropped below 35 knots or when they reached land and were no longer menaces to shipping. To remedy this bias in its catalog of eastern north Pacific tropical cyclones, 1949-1976, the National Hurricane Center recently extended onto land the tracks of all landfall cyclones (Baum and Rasch, 1975; Neumann and Leftwich, 1977). Of these 323 cyclones, 64 (20%) were found to have reached the coast and one or more 12-hour positions could be added to the catalog primarily as rainstorms rather than circular windstorms.

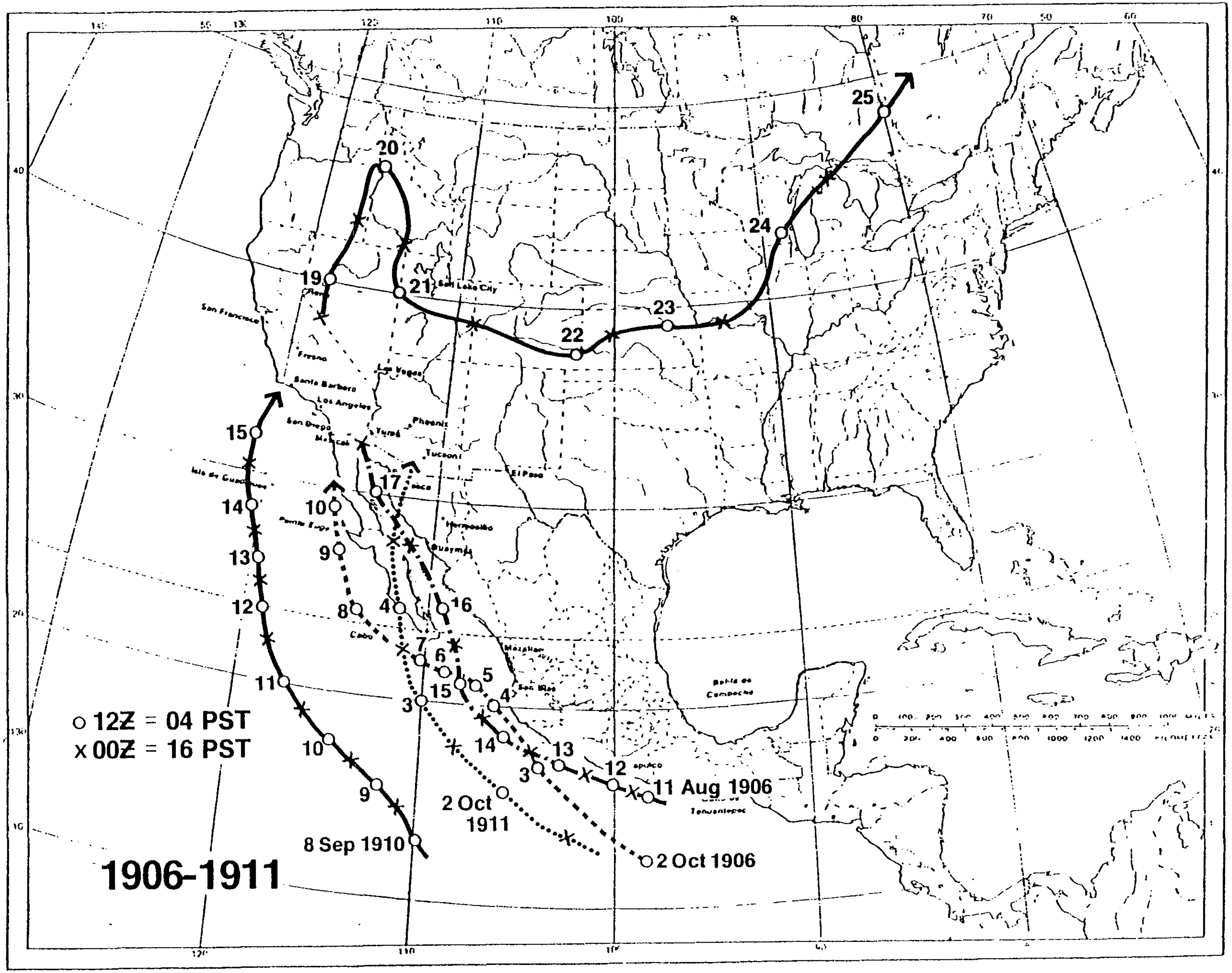

Figure 4. Tropical Cyclone Tracks, 1906-1911

IV. IDENTIFICATION

Tropical cyclones affecting California and Arizona have been identified through comparison of differing official publications of the Weather Bureau (since 1971 separated into the National Weather Service and the Environmental Data Service, both of NOAA). For the first two decades of this century, the primary sources were Daily Synoptic Series Historical Weather Maps compiled during World War II for the 40-year period from July 1899 to June 1939. Effects of cyclones found on these maps were sought in Climatological Data and in the Monthly Weather Review.

At least three tropical cyclones have been traced from Mexican waters into California and thence completely across the country in 1910, 1918, and 1921. Since then, increasing knowledge and observational detail have shown no comparable long tracks.

The first tropical cyclone to be positively identified as entering California began south of Acapulco on August 11, 1906, traveled just offshore and up the Sea of Cortez to the Colorado River valley on the 18th (Figure 4).

> "Phenomenally heavy rains occurred in portions of Southern California... At Needles the total for the month was 5.66 inches, or more than double the total annual average." (McAdie, 1906.)

Indio had 1.07, Mecca 2.00, Cuyamaca 3.00, Campo 2.12, Imperial 1.92, Nellie 1.39, and Warner Springs 1.72; San Diego had only 0.10, Los Angeles 0.03. In Arizona, Yuma reported 1.69, Signal 2.58, Fort Mohave 2.70, and Mohawk 3.05. Two months later another cyclone began farther south on October 2, 1906, went west of Baja California and reached Ensenada on October 10, 1906, before dissipating, with little effect in California.

The first tropical cyclone known to have reached the San Joaquin valley began far south of Cabo San Lucas on September 8, 1910, went north-northwest nearly 1,000 km offshore and was last apparent on surface weather maps on the 15th about 300 km south of Point Conception. Three days later an extratropical cyclone appeared around Lake Tahoe, moved north then southwest through Nevada, then eastward to the Great Lakes and Newfoundland. More than 4 inches of rain fell in Ventura and Santa Barbara counties 14-16 September: Santa Barbara had 2.50 inches. The central San Joaquin valley received about 1 inch in mid-September, damaging drying raisins. At Fresno, three previous Septembers (1890, 1898, and 1904) had received more than an inch, but not until 1976 was this amount again equaled. Heavy rains in the headwaters of the Yuba and Feather Rivers caused them to rise.

"Rain from a disturbance of the Sonora type occurred from the 8th to the 10th" of August 1908, the Monthly Weather Review reported (36:233). Thunderstorms were reported August 2-6 in the high Sierra and the Colorado River valley. No such storm appears on the Review's cyclone track maps nor on the Northern Hemispheric maps nor is mentioned by either Visher or Hurd. On October 1, 1911, a cyclone formed 600 km south of Tehuantepec, went northwest and then north to cross southern Baja California and up the Sea of Cortez. It brought widespread rains to southeastern California, southwestern Arizona, parts of Nevada and Utah, and even flash floods in the San Juan basin of Colorado.

The cyclone that Kimball (1917) reported began 300 km south of Acapulco on August 23, 1915 (Figure 5), went west of Baja California and dissipated southwest of San Diego, where La Jolla received 0.90 inches of rain, Julian 1.73, and Riverside 1.01 in 90 minutes. Almost the same track was followed a year later by

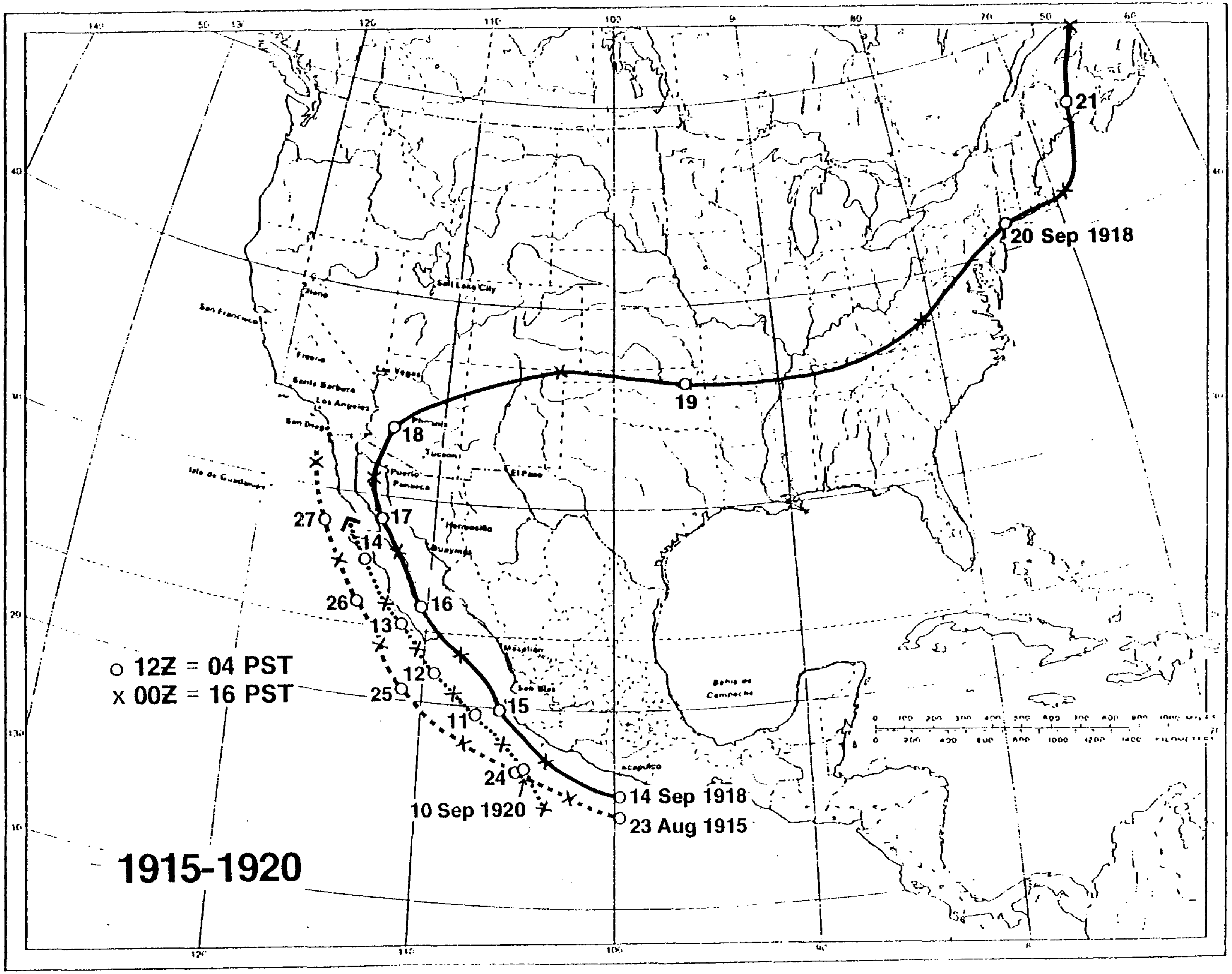

Figure 5. Tropical Cyclone Tracks, 1915-[illegible]

a cyclone which formed off Acapulco on September 14, 1918. Two days later it devastated La Paz and nearby communities, but "extended very little northeast or west of La Paz" (Tingley, 1918). However, 36 hours later a low-pressure area formed near Yuma and traveled northeast across the country to Newfoundland without causing much rain--Arivaca, northwest of Nogales, reported 1.50 inches on the 18th but no more than 0.10 was reported elsewhere in southwest Arizona and none in southern California.

In September 1920 another cyclone penetrated as far as southern Baja California bringing widespread rains to southeastern California, southwestern Arizona, Nevada, and Utah. The following year (August 15, 1921) a cyclone formed south of El Salvador and crossed Baja California to the Sea of Cortez. The cyclone died on the 19th, sending heavy rains into southeast California (Needles 2.10 inches) and Arizona (Ashdale Ranger Station 6.25 inches). Phoenix had 3 inches, flooding the capital (Figure 6).

The third transcontinental tropical cyclone was on the Isthmus of Tehuantepec on September 22, 1921. Vazquez Schiaffino (1927) shows it as originating near Swan Island in the Caribbean on the 19th, but the official U. S. atlas of Atlantic tropical cyclones (Neumann et al. 1978) has no storm in that region on those dates. The storm traveled west, then northwest along the coast of Baja California, moving inland over Ensenada. The storm then turned eastward to Flagstaff and moved across the central United States as an extratropical cyclone, crossing near Detroit, down the St. Lawrence River, across Newfoundland, and across the Atlantic Ocean almost to Ireland.

> "At many stations in southern California and Arizona it produced the greatest rainfall ever recorded in September, and, since its arrival was wholly unexpected, caused much damage to crops and drying fruit." (Blake, 1935.)

Nellie, northeast of San Diego, received 4.15 inches of rain in 24 hours. Beaumont, California, had 3.45 inches and Yuma 3.63 (more than the annual average). For the next seven years, no tropical cyclones appear to have gone past Punta Eugenia or Guaymas at 29°N (Allen, 1925). Only four went even that far--in September 1924, October 1926, and twice in September 1927 (Figure 7).

V. FLOODS

Another tropical cyclone which traveled over much of the United States from Mexico's west coast, but did not pass through California, originated due south of Cabo San Lucas on October 3, 1930. The storm went northeast across Mexico and then northward up the Mississippi Valley, eventually reaching Greenland (Figure 8). The year before, a cyclone which originated off Guatemala on September 10, 1929, skirted the coast all the way to southern California. At San Diego a rare heat wave (max 111°F at El Cajon, September 16, 1921) ended with light rain (Blake, 1929) as the moist air from the storm moved into southern California and as far as the Central Valley--"the first cyclone of the Mexican west coast during the 20-year period 1910-1929...to have pursued a course thus northward into California" (Hurd, 1929b). One had done so in 1906 and another would do so in 1935.

In 1932, two storms formed in the Gulf of Tehuantepec a month apart. Both storms went up the Sea of Cortez, drenching Arizona twice in one summer. The first storm formed on August 25, 1932. It skirted the coast and went inland

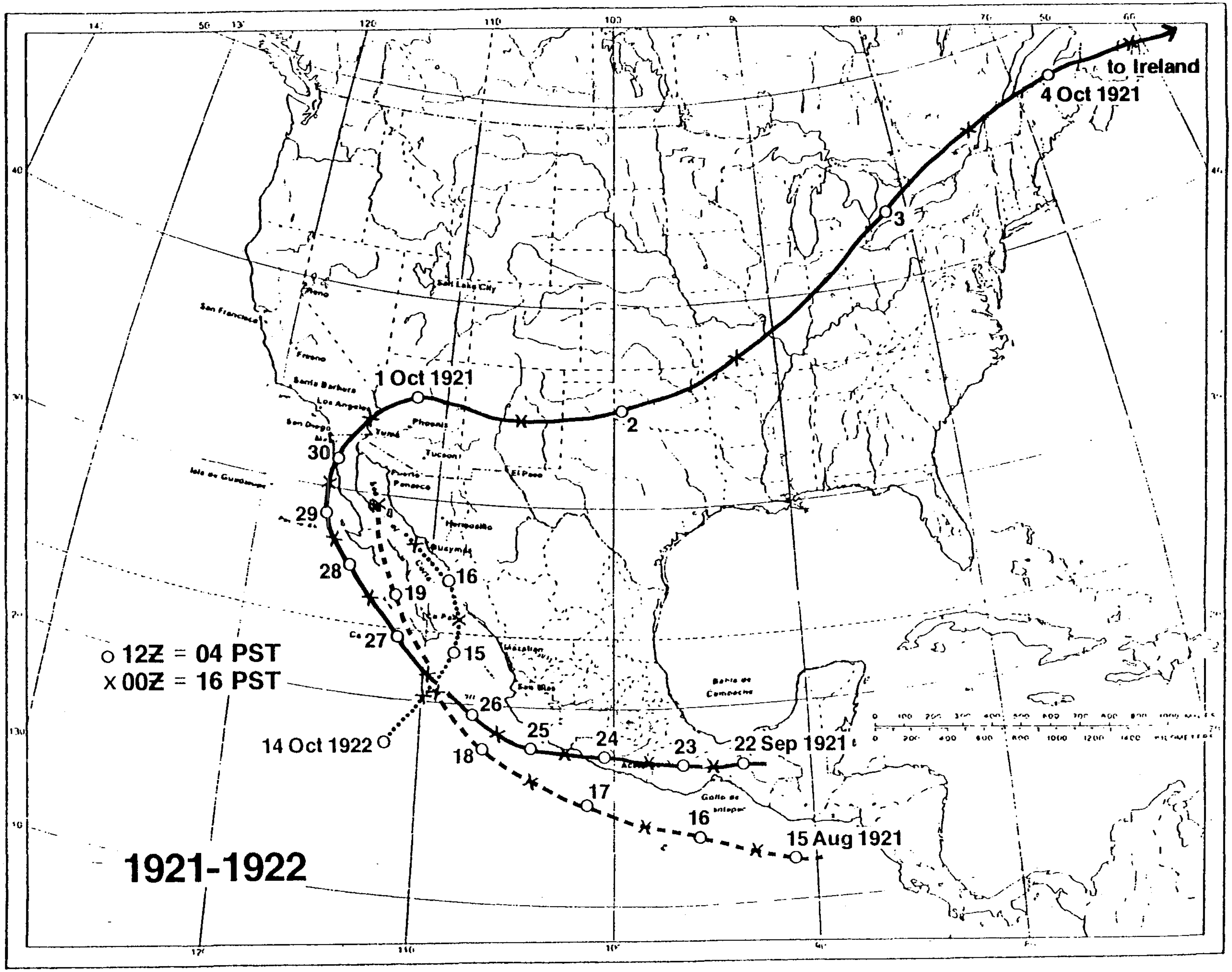

Figure 6. Tropical Cyclone Tracks, 1921

around Culiacan, bringing heavy rains to southwestern New Mexico, August 27-29, 1932. Destructive rains in the Tehachapi mountains of southern California resulted from the second tropical cyclone which began south of Tehuantepec on September 25, 1932. This cyclone remained 100 to 200 km offshore (just grazing Cabo Corrientes) until it reached the head of the Sea of Cortez on the 29th and dissipated in the southwestern deserts (Figure 7). On the last three days of September in Arizona, Truxton had 2.27 inches, Fort Mojave 2.32, and Payson 1.50 inches. In California, Tehachapi had 4.38 inches in 19 hours, but Los Angeles had only 0.14 and Santa Barbara 0.11 (Sprague, 1932).

After a short-lived cyclone had traveled from west of Acapulco to northwest of La Paz August 5-9, 1935, a major hurricane formed slowly in the Gulf of Tehuantepec after August 17, 1935. The hurricane went inland behind Acapulco and traveled through the coastal waters all the way to the Channel Islands, where it filled on August 26, 1935 (Figure 9). One stream of moist air went northward to give Oxnard .43 inches, Ojai .32, Ventura .21, Santa Barbara .27, Betteravia .40, Santa Maria .25, and San Luis Obispo .71 inches during the period August 25-28. Another moist current reached across the Los Angeles basin and rose up the west flanks of the San Gorgonio mountains. San Bernardino had 1.28, Redlands 1.39, Mill Creek 2.37, and Seven Oaks 1.49 inches. "California's statewide precipitation was over three times the normal amount and the greatest of record for August. ...general rains occurred from the 23rd to 28th as a result of the northwesterly movement of a tropical air mass over California." (Sprague, 1935.)

The next year, two cyclones traveled the Sea of Cortez. One, which formed far south of Mexico on August 4, 1936, passed over La Paz two days later and dissipated south of Yuma.

> "The air mass went much farther as unstable air aloft, and caused thunderstorms over the plateau and even over the northern Rocky Mountains, for several days thereafter. ...Even after the vortex was no longer discernible at the surface, the remaining unstable air mass was carried northward almost to the Canadian border." (Blake, 1937.)

While the storm was losing identity near Yuma on Saturday, August 8, 1936, the circulation around it brought "probably the most uncomfortable day of the summer in the Los Angeles area" (Ward, 1936). Maximum temperatures were 93°F downtown and 100°F in North Hollywood (with dew point of 66°F), although there were occasional sprinkles from variable clouds moving in from the southeast. Shortly after 6 p.m., "a peculiar arch of smoke and dust" brought a little rain, then clearing and drier air. The 5-minute average wind of 25 mph was 4 mph stronger than ever previously recorded in July or August in Los Angeles.

"Several places had the greatest August rainfall of record" in the California deserts and southern mountains, including 2.39 inches in 24 hours at Seven Oaks. On the California-Nevada border, Bridgeport, California, had 1.71 inches and nearby Shields Grove 1.45, while across in Nevada at Caliente 1.05 inches fell, with 1.40 at Cedar City, Utah. "On the 8th, a wind and rain storm struck the central and southeastern parts of" Arizona. "Railroad tracks were washed out near Tucson; highways were blocked, railway, bus and airline schedules were disrupted; roofs were swept away and trees uprooted at Phoenix." (C.T.T., 1936.)

A month later on September 8, 1936, another tropical cyclone formed in the same region south of Acapulco. The storm went farther west before recurving to

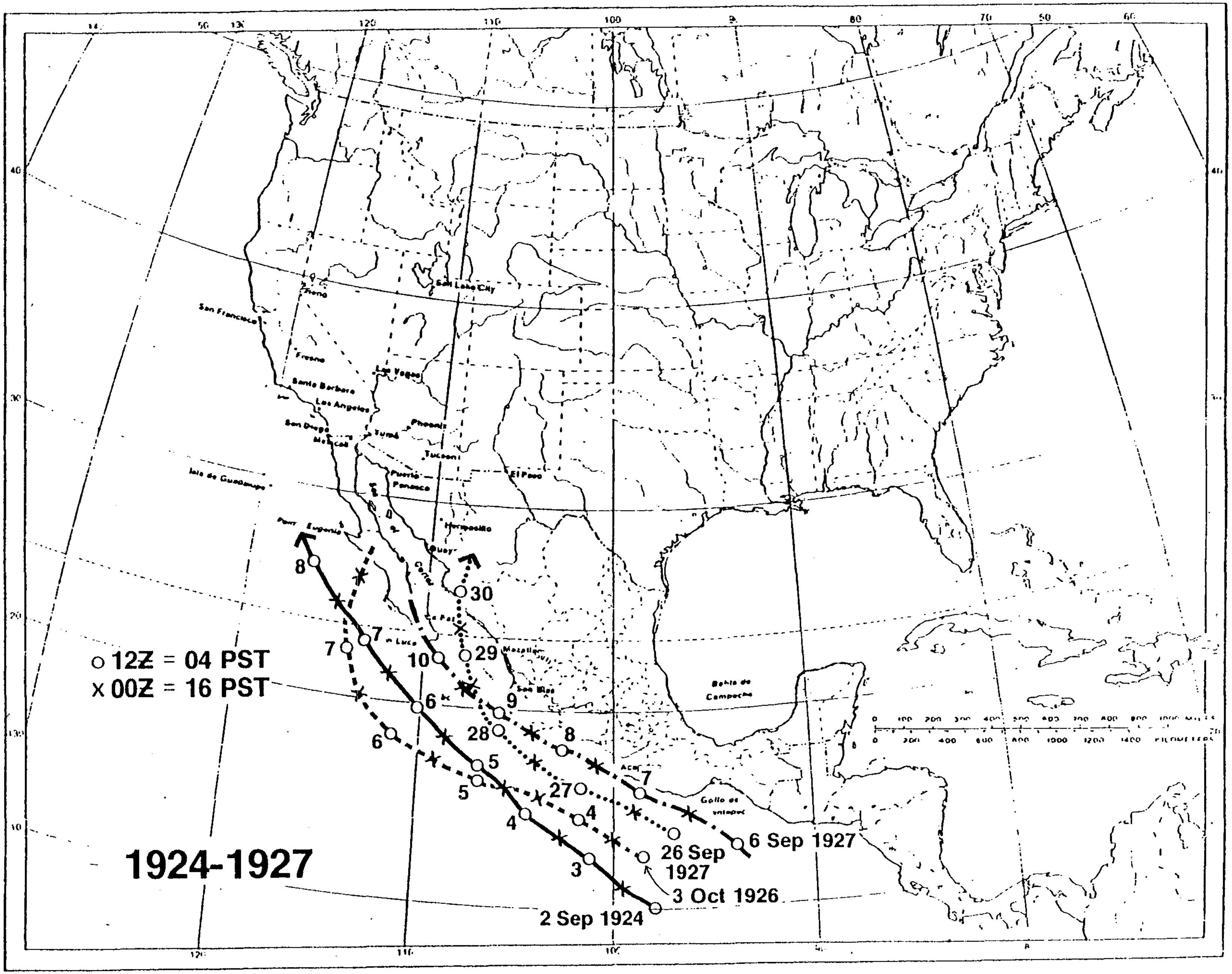

Figure 7. Tropical Cyclone Tracks, 1924-1927.

cross Baja California, the Sea of Cortez, and the Sonora Desert, dissipating in southeast Arizona, where Bisbee received 3.08 inches in two days. Several places in southwestern New Mexico had more than an inch: Datil 1.97, Fort Bayard 1.28, Augustine 1.20, Hood Ranger Station 1.10, Horse Springs 1.34, Luna Ranger Station 1.41, and Quemade 1.15 inches.

VI. FOUR IN A MONTH

In 1937 and 1938 no tropical cyclones came north of 25°N, but the year 1939 more than remedied the deficiency--four tropical cyclones affected southern California in a single month, the fourth and last causing extensive flooding in the Los Angeles basin (Figure 10). The first went almost straight north to Yuma where 4.45 inches of rain fell in three days September 4-6, 1939. "Unprecedented heavy rains in the western half" of Arizona during September 4-6 and September 11-13, 1939, led to new monthly records at 17 stations. According to the Arizona Climatological Data, 24-hour records were broken at seven places on September 4th, 5th, or 6th. In California, rains on September 4-7 exceeded 5 inches at Iron Mountain, Needles, and Hayfield Reservoir and totaled 6.43 inches at Brawley.

Meanwhile, two more tropical cyclones had formed 1,000 miles apart off central America on September 5, 1939. They followed similar paths, dying in central and southern Baja California a week later, sending more moist air northward to the Colorado desert in mid-month. A few days later on September 15, 1939, the fourth cyclone formed off northern Panama and intensified rapidly to hurricane status. The lowest pressure of 970.9 mb (28.67 inches of mercury) came on September 22, some 400 km (300 miles) west-southwest of Cabo San Lucas. Slowly recurving, the storm passed Guadalupe Island early on Sunday (24th) and entered the Los Angeles basin that afternoon.

Since Tuesday, while this cyclone was still growing south-southwest of Acapulco, thunderstorms brought light rain to various parts of the basin (perhaps with moisture from the previous cyclone that had dissipated south of Ensenada more than a week before). On Saturday, the thermometer at the Los Angeles Federal Building reached 101°F before light rain at 4:40 p.m. cooled things off. Clouds thickened and lowered on Sunday, holding the maximum temperature to 81°F. As the center of the dying storm neared Catalina, winds increased in the afternoon, gusting to 50 mph from the southeast at 7 p.m. Rain began at 5 p.m. and increased in intensity during the night, becoming heavy between 1 and 8 a.m. Monday. Rain stopped from 10:15 a.m. until 5:35 p.m., then resumed until 1:15 a.m. Tuesday. Total rainfall September 24-26, 1939, at Los Angeles was 5.62 inches with Long Beach reporting 4.51, Claremont 4.89, Santa Ana River 4.41, and Squirrel Inn 9.01 inches. Mr. Wilson reported 9.02 inches on Sunday with a 3-day total of 11.60 inches. At sea, 45 lives were lost in this storm. Damage to small boats, shore structures, power and telephone lines exceeded 1.5 million dollars. Half a million dollars damage to crops by strong winds and "unprecedented September rains" was done (Sprague, 1939).

On Saturday, September 24, 1939, an intense thunderstorm at Indio dropped 6.45 inches in 6 hours (5 to 11 a.m., PST) with 1.75 inches falling in 45 minutes. Indio had received 2.03 inches during September 4-8 from the first tropical cyclone which went up the Colorado River. Because the heavier rain fell two days before that in the Los Angeles basin, Pyke (1975) feels it developed in moist air moving northward from the Sea of Cortez a week earlier. The moisture

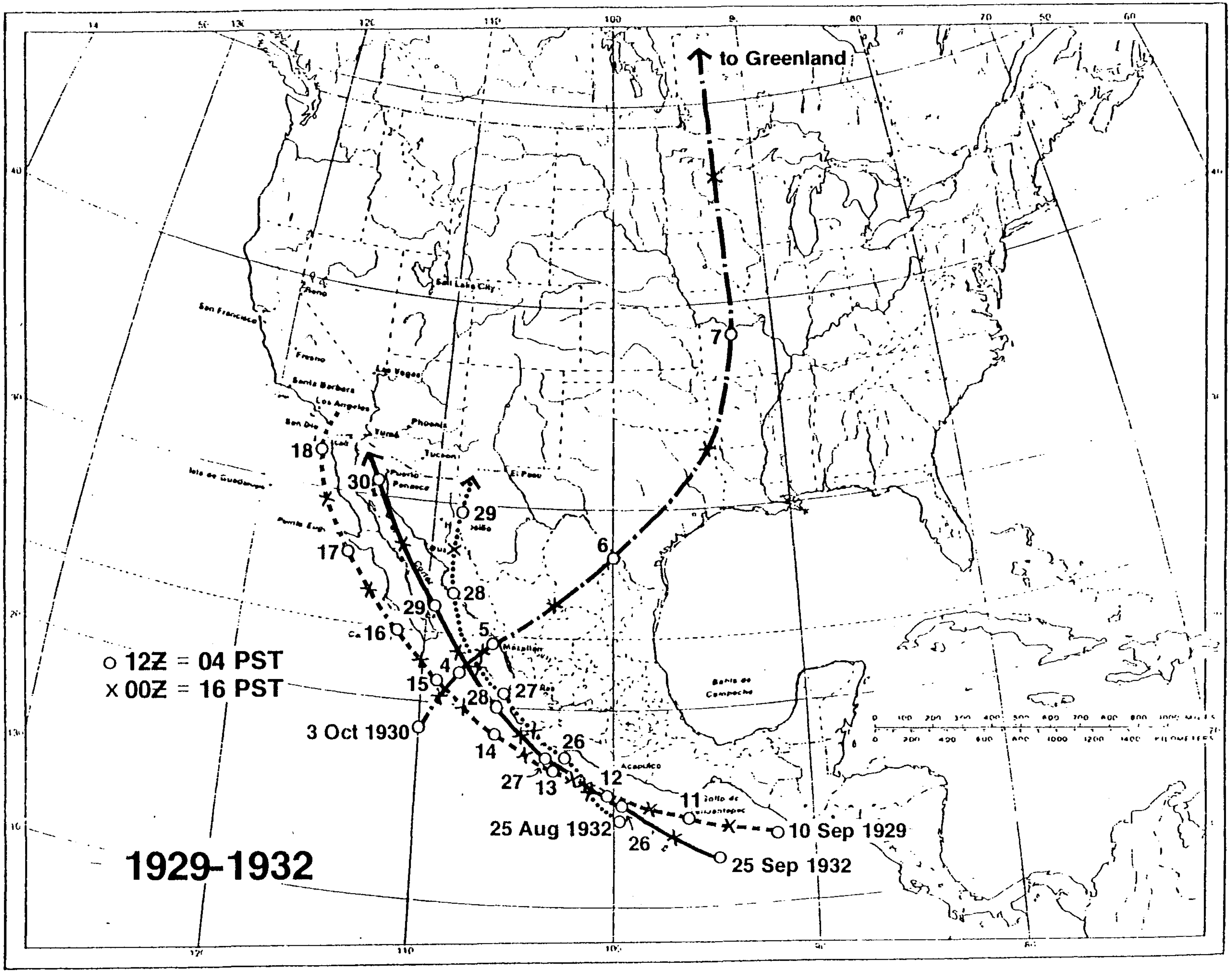

Figure 8. Tropical Cyclone Tracks, 1929-1932

was then deflected westward into the Coachella valley by the circulation around the offshore storm. A month later, October 25, 1939, "the lowest barometer reading on record in connection with a tropical cyclone occurring in southeastern north Pacific tropical waters"--27.45 inch = 929.6 mb (corrected after barometer calibration at the San Francisco Weather Bureau Office)--was made on the U. S. vessel Nevadan at 20°N, 116°-21 W, west of Manzanillo (Hurd, 1940). This is 60 mb higher than the world record low pressure at sea level of 870 mb attributed to Supertyphoon Tip on October 11, 1979, near 15°N, 139°E (about 350 miles west of Saipan) when the storm was 2,100 miles in diameter with 160-knot winds (De Angelis, 1979; Mar. Wea. Log 24: 254, 276, 1980).

VII. POSTWAR

For a quarter century thereafter, no tropical cyclone actually reached southe California, although a score came as far as Cabo San Lucas and a few made it ha way up Baja California. Three almost reached the head of the Sea of Cortez or Sonora desert to the east (Sept. 16-22, 1941; Sept. 24-28, 1946; July 12-17, 19 and contributed some clouds and showers to southern California (Figure 11).

One had an unusual history. Atlantic Hurricane Charlie of 1951 formed 1200 km east of Barbados on August 12, 1951, and traveled almost due west to Yucatan. As it was dissipating in central Mexico on the 23rd, a new cyclone formed off Cabo Corrientes and moved northwestward. It passed far south and west of Cabo San Lucas, then recurved to cross the coast near San Quintin, breaking up in the Sierra San Pedro Martir.

Charlie's moisture had "caused torrential downpours over Mexico during the last ten days of August; flooding there caused over 400 deaths" (Oliver, 1951). Moisture from the Pacific storm was added to this and "rains spread across Arizona...northeastward from the southwest border" (Carr, 1951). In four days (August 26-29, 1951), Yuma had 1.13 inches, Prescott 2.58, Phoenix 3.80, Payson 7.77, Flagstaff 3.00, and Winslow 1.30 inches. Meanwhile Tucson, "to one side of the main flow", had only 0.62 inch on the 29th. In California:

> "Heavy rains on the 28th ended a four-month dry period in San Diego county. The total of 0.85 inch of precipitation for San Diego in August was exceeded only three times since records began in 1850: 1.36 inches in 1853, 1.95 inches in 1873, and 0.87 inches in 1939...The monthly total precipitation at Los Angeles, 0.15 inch, was the greatest of record for August...Light to heavy thunderstorms during the last week brought light to heavy rains to the Imperial and Coachella valleys. Many roads were washed out in Imperial county." (Englebrecht, 1951.)

In both 1957 and 1958, tropical cyclones reached the vicinity of Guadalupe Island, and others went into the Sonora Desert to bring October rains to southwestern Arizona (1957) and southwestern New Mexico (1958) (Figure 12). A cyclone which began August 9, 1957, far south of Cabo San Lucas was no longer an organized storm after passing Guadalupe on the 15th but sent its moisture northeastward:

> "On the 19th, an intense thunderstorm with locally heavy rain and high winds caused damage over a wide area from southern portions of Imperial valley northward to the Riverside

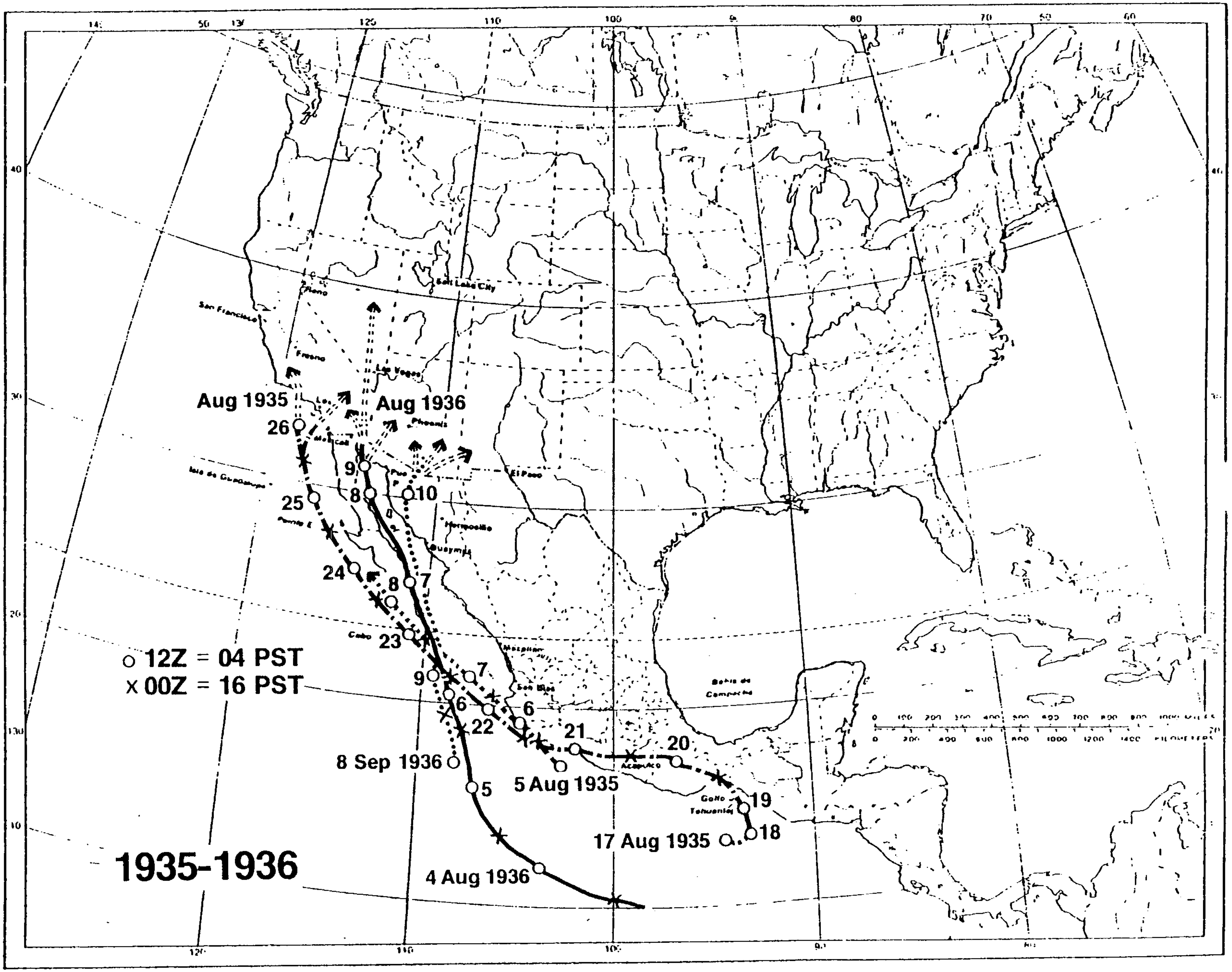

Figure 9. Tropical Cyclone Tracks, 1935-1936.

County line. Winds downed telephone and power lines and damaged television antennas. Many dips on Highways 99 and 111 were full of water, and highway traffic was disrupted in many places. Highway 111 was partially closed when mud several feet thick drifted across the route. At least one highway accident was attributed to the storm that occurred east of Holtville injuring seven people. Heaviest reported rain, 0.62 inches, fell east of Calexico." (Bergerson, 1957.)

Likewise, a day after the second storm broke up around Guaymas on October 5, 1957, half-inch rains were common in southeast Arizona. The heaviest rainfall was 1.10 inches at Rucker Canyon. A flash-flood north of Benson destroyed mining equipment (Kangieser, 1957). The western cyclone of 1958 brought little rain to California, and the eastern one brought only scattered rains to New Mexico. The following year a hurricane, which began in the Gulf of Tehuantepec on September 4, 1951, spent most of its energy in the open sea doing little damage as it passed east of La Paz, crossed Baja California, and went up the west side to dissipate around Ensenada on the 11th.

Names have been given to Atlantic tropical cyclones for almost 30 years but only for 20 years in the eastern Pacific. In 1950 serial numbers that had been given annually (1949-I, 1949-II, 1949-III, etc.) were replaced by letters of the phonetic alphabet (1950-Able, 1950-Baker, 1950-Charlie, etc.). Two years later, when the alphabet was changed to an international flavor (Alpha, Bravo, Coco, etc.), selected names were given in alphabetical order. All were feminine; chauvinistic reasons ranged from unpredictability to "they're not himicanes". Strident protests from advocates of feminine liberation led to alternating male and female names, starting in 1978 (Table 1).

Because not enough names beginning with Q, U, X, Y, or Z are available, each year's list has only 21 names, enough for the eastern Pacific but not for the central and western Pacific. There cyclones are named from a set of 84 names (four alphabets) without a break. At the end of the fourth set, the first one is used again except for names of especially famous hurricanes which are retired for ten years.

Assigning names serially in each ocean sometimes causes confusion, as when a storm crosses central America. In 1961, Caribbean Hurricane Hattie crossed Guatemala to become Pacific Storm Simone and then crossed Tehuantepec to be renamed Inga (Figure 13). This double reincarnation (Randerson, 1963) is not recognized by the official atlas of north Atlantic tropical cyclones (Neumann et al. 1978) which shows Hattie and Inga unconnected and no Simone. The atlas does indicate two metamorphoses a decade later--Caribbean Irene (Sept. 11-20, 1971) into Pacific Olivia (Sept. 20-30), and Atlantic Fifi (Sept. 14-22, 1974) into Pacific Orlene (Sept. 22-24).

Irene crossed over Managua, Nicaragua, on September 20, 1971, to become Olivia and die 10 days later in southcentral Baja California. Born on Africa's west coast on September 7, Irene had reached the Antilles in a week. Still a tropical depression, she crossed over Curacao on the 16th. In the southwest Caribbean, she became a hurricane. She then lost strength in crossing Nicaragua and as Olivia became "the first known Atlantic hurricane to cross into the Pacific with almost immediate regeneration into a tropical storm". (DeAngelis, 1972.)

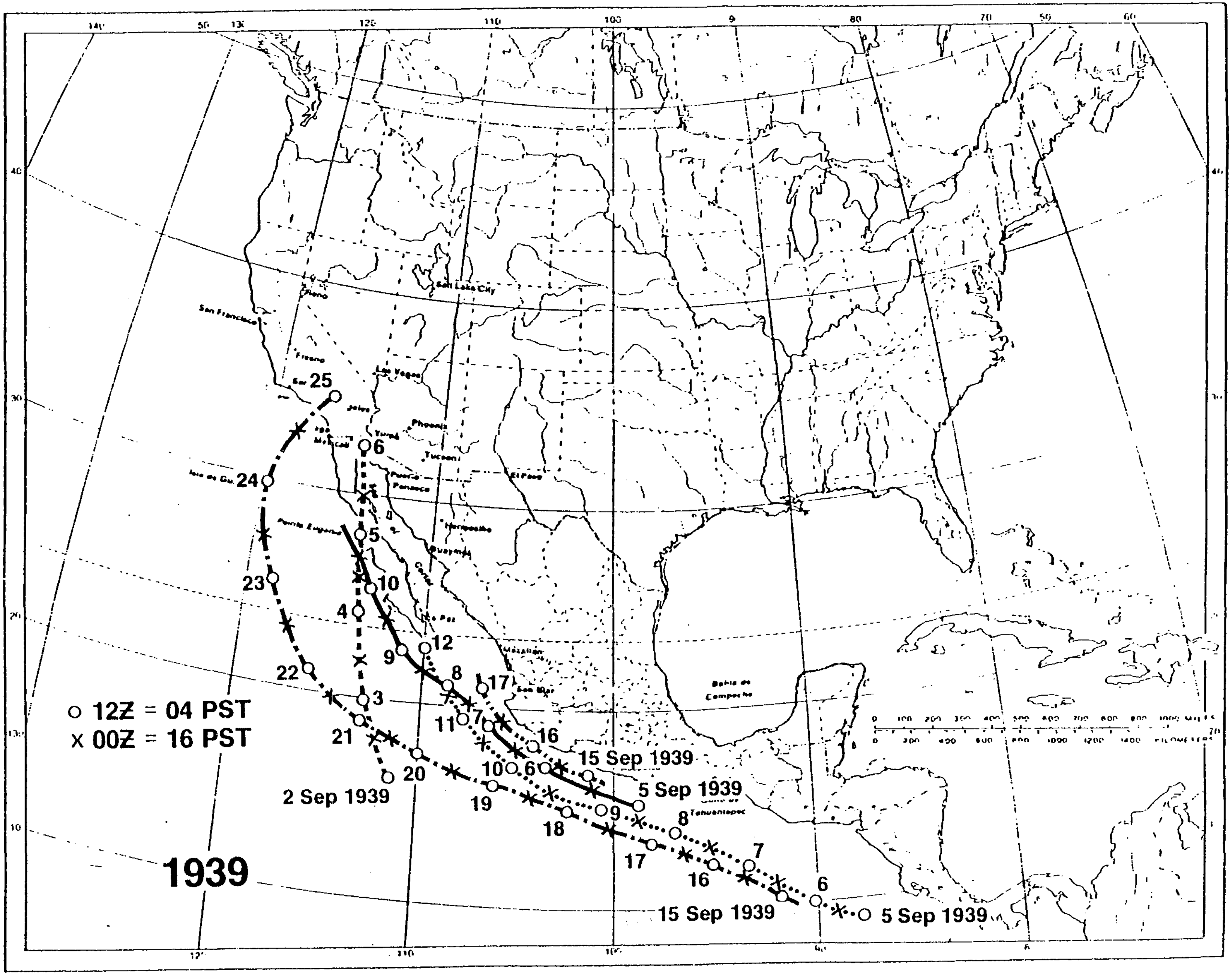

Figure 10. Tropical Cyclone Tracks, 1939.

TABLE I

NAMES OF TROPICAL STORMS AND HURRICANES IN THE EASTERN PACIFIC OCEAN
1978 - 1983

1978	1979	1980	1981	1982
Alletta	Andres	Agatha	Adrian	Aletta
Bud	Blanca	Blas	Beatriz	Bud
Carlotta	Carlos	Celia	Calvin	Carlotta
Daniel	Dolores	Darby	Dora	Daniel
Emilia	Enrique	Estelle	Eugene	Emilia
Fico	Fefa	Frank	Fernanda	Fabio
Gilma	Guillermo	Georgette	Greg	Gilma
Hector	Hilda	Howard	Hilary	Hector
Iva	Ignacio	Isis	Irwin	Iva
John	Jimena	Javier	Jova	John
Kristy	Kevin	Kay	Knut	Kristy
Lane	Linda	Lester	Lidia	Lane
Miriam	Marty	Madeline	Max	Miriam
Norman	Nora	Newton	Norma	Norman
Olivia	Olaf	Orlene	Otis	Olivia
Paul	Pauline	Paine	Pilar	Paul
Rosa	Rick	Roslyn	Ramon	Rosa
Sergio	Sandra	Seymour	Selma	Sergio
Tara	Terry	Tina	Todd	Tara
Vicente	Vivian	Virgil	Veronica	Vicente

TABLE 2

ANNUAL NUMBERS OF TROPICAL CYCLONES AND HURRICANES IN THE EASTERN
NORTH PACIFIC FOR VARIOUS PERIODS

Years	Cyclone	Hurricane	Author
1910-1940	5.7	2.2	Hurd (1941 et seq.)
1947-1951	6.0	2.4	Kalstrom (1952)
1947-1961	7.5	3.2	Rosendal (1962)
1949-1966	8.9	3.7	DeAngelis (1967)
1961-1968	15.4	3.8	Harris (1969)
1958-1969	11.2	4.0	Rosenthal (1972, p.10.6)
1966-1972	15.3	6.7	Baum (1973)
1965-1974	15.7	6.6	Renard and Bowman (1976)
1954-1963	9.4	5.4	Eidemiller (1978)
1964-1976	18.2	9.9	Eidemiller (1978)
1965-1977	14.5	6.8	DeAngelis (1979)
1966-1979	14.4	7.4	Gunther (1980)

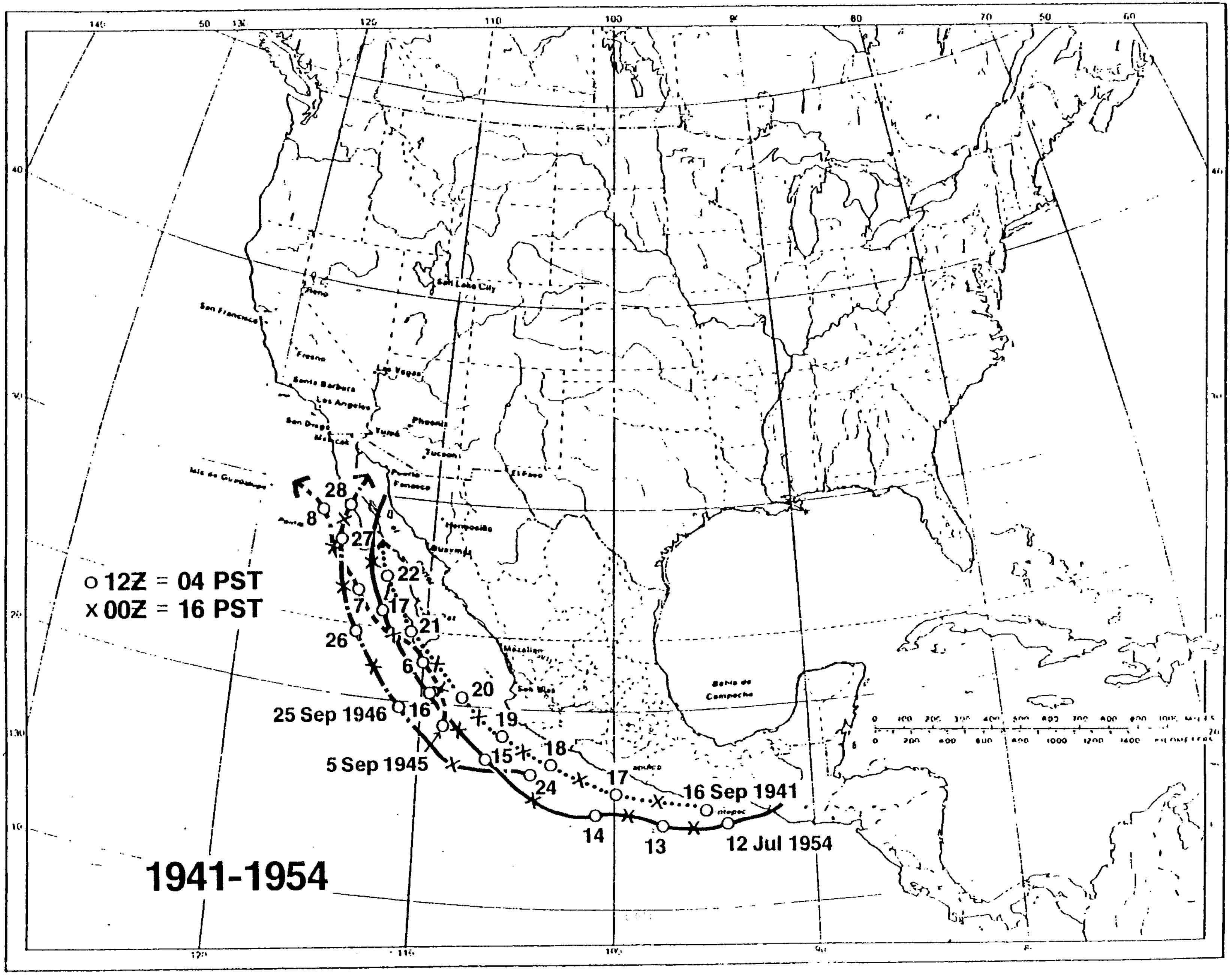

Figure 11. Tropical Cyclone Tracks, 1941-1954

VIII. ARIZONA DOWNPOURS

Diana devastated La Paz on August 19, 1960, and both Orla (September 6-11, 1961) and Claudia (September 20-24, 1962) died off Punta Eugenia, sending moisture northward without spectacular effects. Katherine went ashore near Ensenada on September 18, 1963, and southern California suffered slight damage from rain, wind, and surf.

> "Bakersfield experienced the wettest September since 1903... Precipitation at Burbank has been exceeded in September only in 1939; 5 days of rain this year are the greatest number ever recorded in September. San Diego and Los Angeles City reported the second wettest September of record; Los Angeles airport the third wettest." (Elford, 1963.)

Part of this was from a storm two weeks earlier, apparently not connected with any tropical storm. "On the 4th and 5th the desert area of southern California received damage from highway flooding, downed trees, and utility lines", and the San Joaquin valley reported damage to raisins. "Southern and central California received similar damage on the 12th and 13th", when the only disturbances--Irah and Jennifer--were far south and southwest of Cabo San Lucas.

In 1964 Sylvia and Tillie (August 23-24 and September 29, respectively) reached no farther than the waters west of southern Baja California, as did Claudia (August 5-10, 1965) and Emily (August 29 to September 4, 1965), and a year later Helga (September 9-15, 1966) did the same. Finally, on August 29, 1967, Katrina formed off Acapulco, moved northeastward across Baja California north of La Paz, and went up the Sea of Cortez and the Colorado River (Figure 13). She dumped two inches of rain on Yuma in three days. Later that year, Lily (September 5-11, 1967) wandered far west of Baja California before dissipating, and Olivia (October 5-14) crossed the peninsula twice before expiring in Scammons Lagoon.

In 1968, two cyclones passed near La Paz, crossed the Sea of Cortez, and headed due north across Sonora toward Nogales. Hyacinth (August 16-20) brought more than an inch of rain to a score of southeast Arizona communities with 2.16 inches near Elgin and 1.60 at Coronado National Monument, just to the east. Meanwhile, southwest Arizona was dry. Two months later, Pauline (October 26-30) brought rains of half-an-inch or more to the southwest--not the southeast. Bouse (near Parker) reported 1.90 inches while in California, Iron Mountain had 1.73 and Mt. Jacinto 1.02 inches.

The next year Glenda formed off Manzanillo on September 7, 1969. She passed west of Cabo San Lucas on the 10th and turned westward along the 26th parallel. A "surge" of her moist air traveled up the Sea of Cortez to drench central Arizona. A new 1-hour rainfall record for the state was set with 3.52 inches in a thunderstorm at Tempe on September 14, 1969. Two days later "another storm set several short-period records at the Phoenix Sky Harbor Airport, dropping 1.00 inch of rain in a 10-minute period" (Hales, 1972). A month earlier, a similar "surge" from Emily (August 22-24, 1969) sent moist air northward decreasing temperatures and raising dew points at Yuma, Blythe, Needles, and Las Vegas without producing rain.

In 1970, tropical storm Norma, located off Baja California 600 miles south of Arizona, "helped create the southerly winds and unstable air that fed

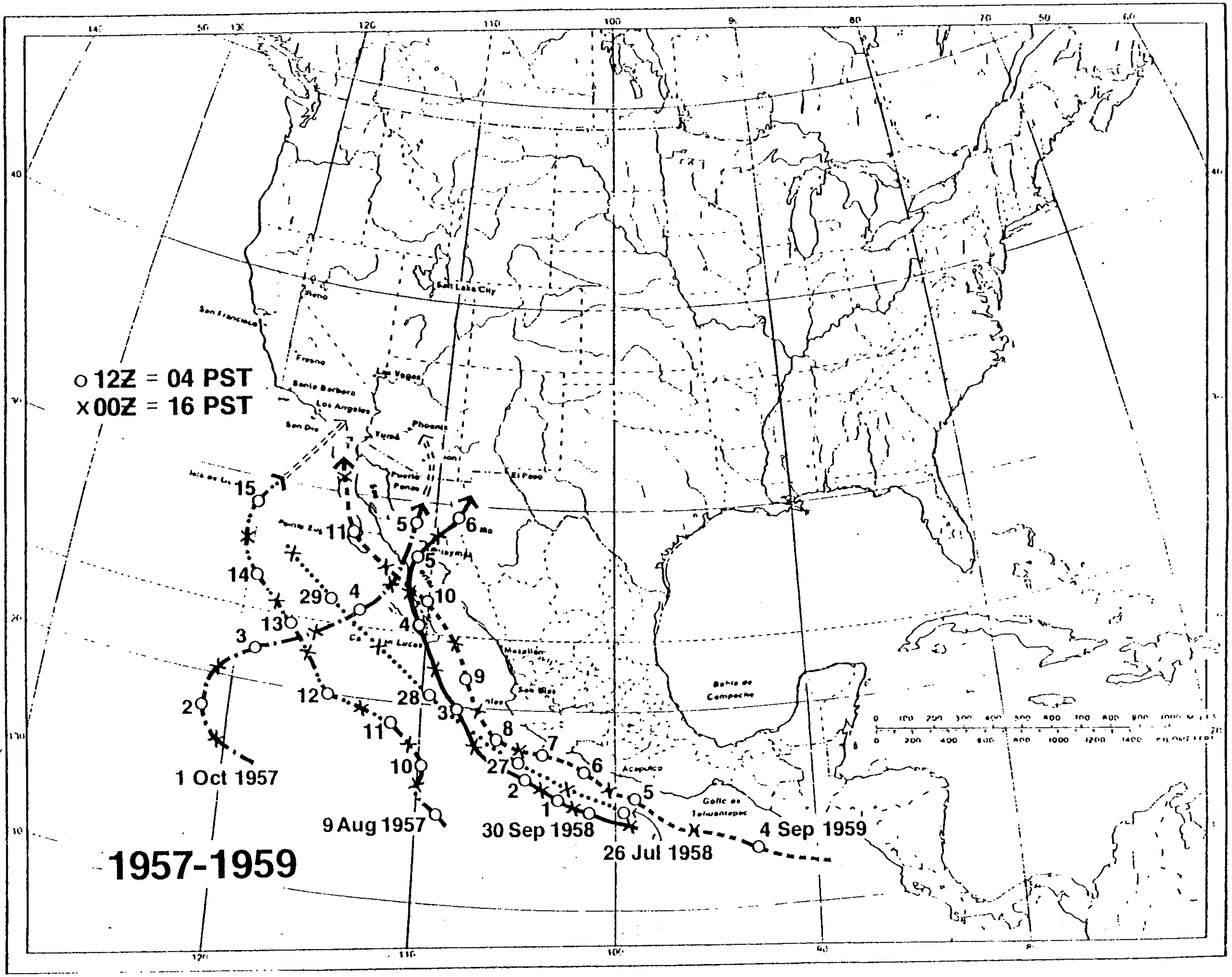

Figure 12. Tropical Cyclone Tracks, 1957-1959.

extraordinary amounts of moisture into the middle-latitude-type storm directly responsible for...the Arizona flood disaster of September 4-6 (22 deaths, over a million dollars damage). ...Norma...dissipated completely on the 5th while approaching the Baja California peninsula near 27°N, 113°W" (Denney, 1971). Details of the widespread rains are given by Hales (1970) and of the damage by Zimmerman et al. (1970). The storms set "a new all-time record for 24-hour precipitation" of 11.40 inches from 10 p.m. to 10 p.m., September 4-5, 1970, at the Workman Creek No. 1 recording gage (6970 ft. = 2124 m) in the Sierra Ancha mountains of east-central Arizona (Kangieser, 1970). This amount has become the "general storm PMP" (probable maximum precipitation) for the southwestern United States (Riedel and Schreiner, 1980).

In 1972, for the first time since 1939, the remnants of a tropical cyclone reached southern California. Another Hyacinth began 300 miles south of the Tehuantepec isthmus on August 27, 1972, traveled west-northwest for a week, recurved at 125°W, and on September 6 "went inland between San Diego and Los Angeles...with only 20-knot winds" (Baum, 1973). The storm brought one-inch rains to some desert stations (Beaumont 1.52, Parker 1.05, and Benton 1.08 inches). Earlier, Fernanda (August 19 to September 1) and Gwen (August 21-23) had both caused 20-foot breakers on southern California beaches (Rosenthal, 1973), but no rains.

IX. THRICE IN A ROW

For two years, 1973 through 1974, no tropical cyclones came close enough to bring southern California either rain or waves. Then three successive summers saw one storm each. Kathleen began on September 6, 1976, some 300 miles southwest of Acapulco and moved northwest to west of Socorro Island (Figure 15). She passed "180 miles west of the tip of Baja California, ...crossed the western tip of Point Eugenia Peninsula (and) moved onshore 140 miles south of Ensenada... Kathleen continued northward over the Sierra San Pedro and Juarez mountains, entering southern California near Calexico at 1800". Winds near Yuma reached 77 mph.

> "Racing across the southern California desert, Kathleen began to weaken. The storm moved northward through Death Valley and into western Nevada, 140 miles southeast of Reno, by 0600 on the 11th. The center was difficult to locate after 0600; however, gusty winds and rain continued to spread northward into eastern Oregon, Idaho, Montana, Utah, and Wyoming.
>
> "The first rain to appear over the southern California desert areas began early on the 9th. By evening, moderate rain was reported at Imperial. By the morning of the 10th, the rain had spread to western Arizona, southwest Utah, southern Nevada, and as far north as Fresno and Bishop. Imperial reported a surface pressure of 997.3 mb at 1800. Yuma reported the highest wind--66 kn. As the storm continued northward through Death Valley and into western Nevada, it was absorbed into a low-pressure system moving inland from the southern California coast. This low-pressure system brought additional rain inland over the coastal and interior valleys of central California.

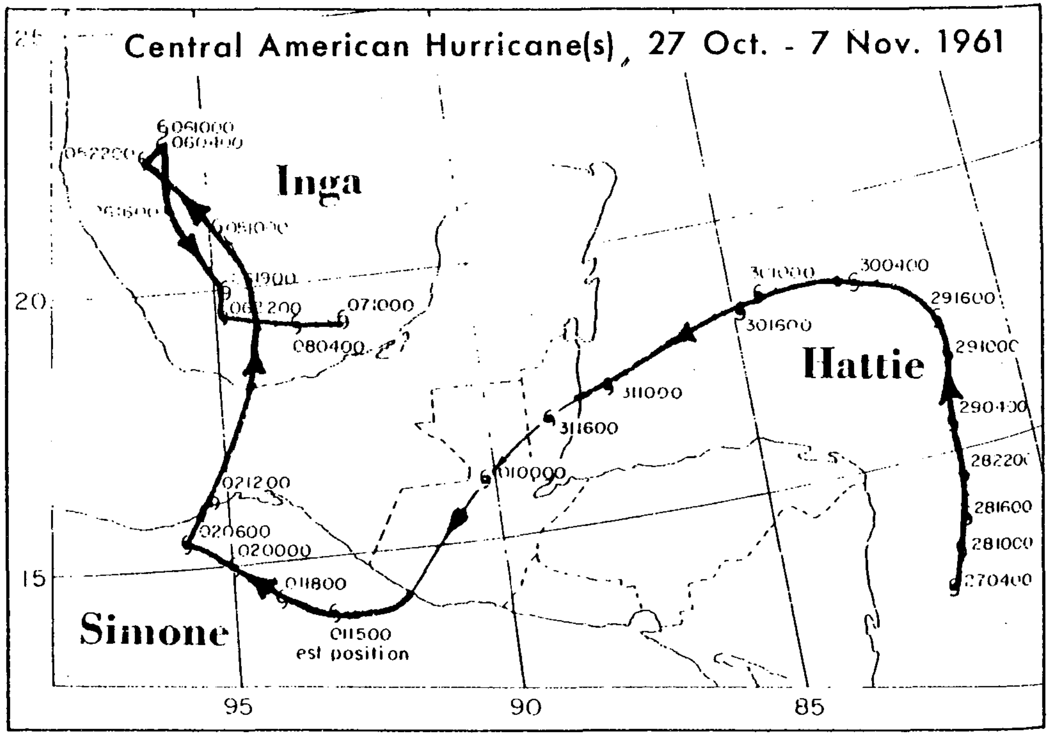

Figure 13. Central American hurricane(s), October-November 1961
(From Randerson, <u>Weatherwise</u> 16:166-168, 174, 196

"Kathleen left 10.78 inches of rain on Mt. Wilson, just north of Los Angeles; 14.5 inches on San Gorgonio Mountain, northwest of Palm Springs, and 10.13 inches on Mt. Laguna, east of San Diego. Lake Arrowhead, east of Los Angeles, reported a storm total of 8.71 inches. The civic center in downtown Los Angeles reported 1.98 inches to bring the season's total to 2.3 inches compared to a normal of .06 inches for the date.

"In the desert, Imperial reported a storm total of 2.22 inches, Yucca Valley 3.36 inches, and Palm Desert, which normally receives only 2 inches per year, received 3.57 inches. Hardest hit by the storm was the desert town of Ocotillo, about 25 miles west of El Centro near the California-Mexico border. A wall of water moving down Myer Canyon destroyed the Myer Creek Bridge on Interstate Highway 8 causing a gap 700 ft. wide and 10 ft. deep through the highway. The wall of water, estimated to be one-half mile wide and 4 to 6 ft. high, destroyed 70 percent of the homes in Ocotillo and severely damaged another 20 percent. Three deaths were reported and at least 100 people were evacuated.

"Flood waters rushing into the Salton Sea raised its level 6 to 8 inches. Several seaside communities were flooded and at least 75 people were evacuated from Salton City. The New River, flowing from Brawley to the Salton Sea, overflowed its banks when silt carried by the river backed up at its mouth. The river, normally 20 ft. wide, swelled to more than one-fourth mile. Flood waters moving through the Carrizo Gorge, northeast of Jacumba, destroyed three bridges and several miles of track of the San Diego-Arizona Eastern Railway.

"Agricultural losses in the Imperial Valley exceeded $60 million. Sand, silt, and mud carried by flood waters changed the topography and ruined much of the farmland and destroyed most of the elaborate irrigation systems necessary for desert farming. In the San Joaquin Valley of central California, most of the raisin crop was destroyed along with late varieties of fruit and nuts; the loss was estimated in excess of $100 million.

"In summary, Kathleen, the first tropical cyclone to hit southern California in 37 years, left five dead in the United States: three in Ocotillo, one in San Bernardino County, and one in Yuma. At least 175 people were evacuated from flooded areas, and losses were estimated in excess of $160 million." (Gunther, 1977.)

Ten days later Los Angeles was visited by the remnants of a real typhoon. Joan formed between Wake Island and Guam on September 19, 1976, moved northward and became a typhoon for a day, then "turned north-northeastward and became extratropical on the 24th", still carrying 40-knot winds. After moving eastward for two days along the 47th parallel, ex-Joan "turned southeastward late on the 26th and moved off the coast of California, finally going ashore near San Diego late on the 29th" without bringing any rain or wind. (Smooth Log, 1977.)

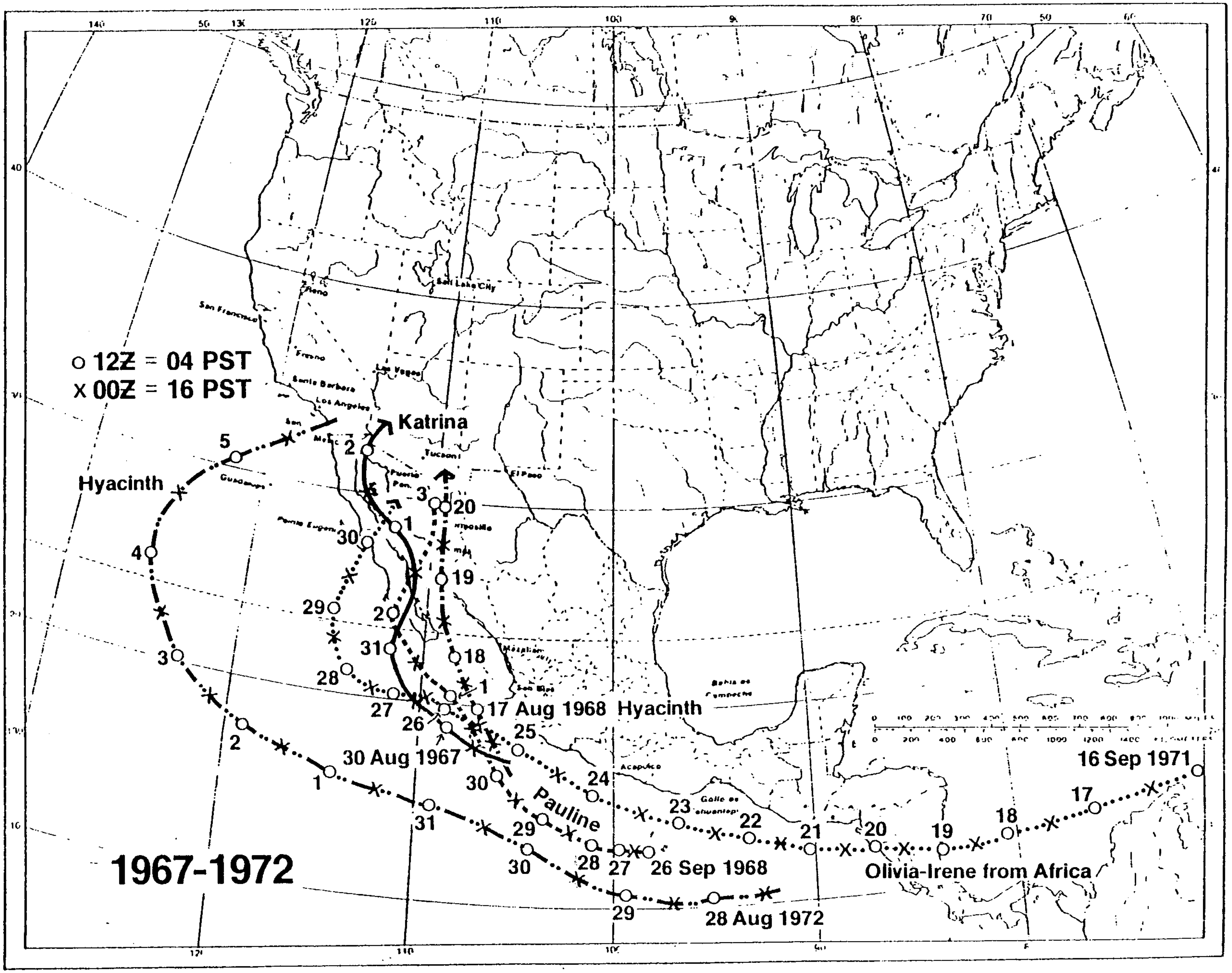

Figure 14. Tropical Cyclone Tracks, 1967-1972.

Doreen began 100 miles west of Acapulco on August 11, 1977, and grew while drifting slowly westward to become a tropical storm on the 13th. Moving north-northwest, she became a hurricane on the afternoon of the 14th and passed 30 miles west of Cabo San Lucas at 1300Z on the 15th. "Turning more to the north-west and increasing its speed to 18 kn, Doreen drifted onshore briefly near San Carlos on the west coast of southern Baja... The hurricane was downgraded to a tropical storm near 26.4°N, 113.2°W. Drifting onshore again, Doreen moved across the tip of the Point Eugenia Peninsula" and an hour later "was again offshore moving northwestward over the Bay of Sebastian Vizcaino" with winds of only 35 kn. By the 17th "winds had decreased to 30 kn and Doreen was down-graded to a tropical depression...130 miles south of San Diego". At 0000 on August 18 the center was 25 miles NNW of San Clemente Island. "Remnants of Doreen then drifted slowly northeastward across southern California."

> "While Doreen was off the central Mexican coast, still south of Baja California, another disturbance was developing near 15° N, 119°W. This latter disturbance began to drift eastward into the cyclonic flow associated with Doreen. Ships within 300 miles of this new disturbance reported moderate to heavy rain. As Doreen moved northward along the Baja California coast, this moisture was carried northward around Doreen and into southern California. This moist tropical air began to enhance shower and thundershower activity over the southern California desert areas on the 15th. Flash flood watches and warnings, already in effect for heavy thundershowers over the Colorado River Valley and eastern desert areas, were extended with heavy rain warnings to most of southern California by the 16th.
>
> "Rain moving northward with Doreen reached San Diego early on August 16, spreading northward to the Los Angeles basin and Mojave Desert by afternoon and Owens Valley and southern San Joaquin Vallay by evening. On the coast rain spread as far north as Santa Barbara by early the next morning. Rain continued over southern California through late evening on the 17th, and a few lingering showers remained in the Los Angeles area until late the following morning. An average of 2 to 4 inches of rain fell over the low-lying areas of southern California during the 3-day period, and as much as 7.5 inches in the higher mountains. A total of 2.13 inches of rain fell at San Diego airport, 3.78 inches at Calexico, 3.87 inches at Imperial, 2.47 inches at Los Angeles airport, 3.14 inches at Santa Monica, 2.61 inches at Mt. Wilson near Los Angeles, and 7.45 inches at Mt. San Jacinto west of Palm Springs. Unusually heavy rain fell at Mitchell Caverns 60 miles west of Needles, where 6 inches was reported on the 17th.
>
> "No deaths in the United States were directly attributed to Doreen, but five deaths were indirectly attributed to the heavy rains and flooding. Damage was extensive, particularly to agricultural interests in the Imperial and San Diego counties. Losses are estimated in excess of $25 million. Flood waters destroyed 325 homes and businesses in the southern desert areas, and several people were evacuated from low-lying areas.

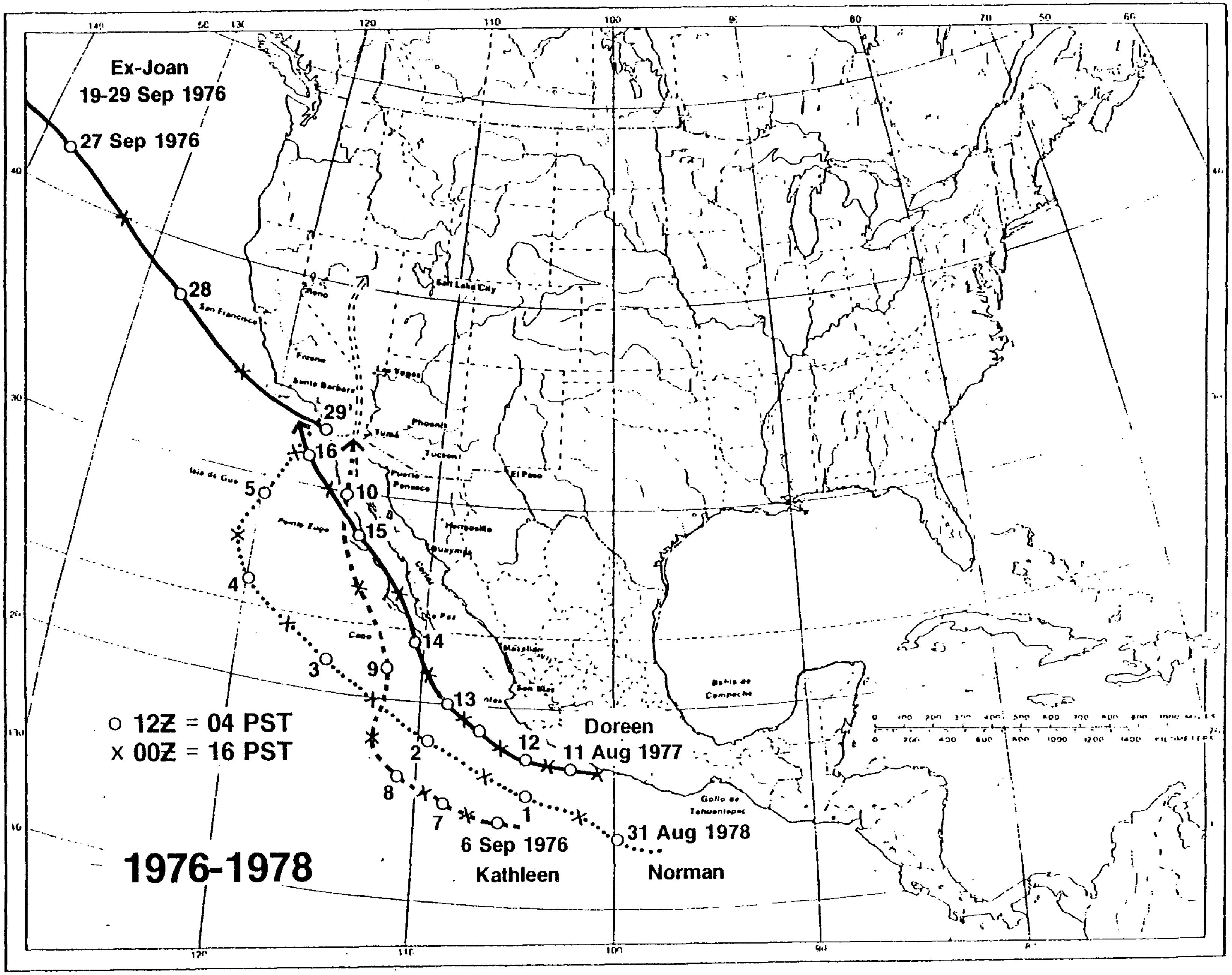

Figure 15. Tropical Cyclone Tracks, 1976-1978.

"The small desert town of Ocotillo was flooded again as it had been during hurricane Kathleen in September 1976. Buses sent to evacuate people from Ocotillo returned empty, however, when the townspeople declined to leave their small community. Interstate Highway 8 at Myers Creek, west of Ocotillo, was washed out again as it had been during Kathleen. Although floodwaters were less than with Kathleen, boulders the size of small cars were observed moving down Interstate Highway 15 between Los Angeles and Las Vegas, and floodwaters carried away two of the four lanes." (Gunther 1978a, b.)

Next year, the third tropical cyclone penetration into southern California occurred when Hurricane Norman, which had formed August 31, 1978, south of Acapulco, abruptly turned right 700 km west of Point Eugenia. The storm weakened rapidly as it passed Guadalupe Island and barely reached Los Angeles as an organized cyclone. "Despite this, Norman's rain shield spread to northern California and most of the northwest corner of the nation. The rain was light but widespread. Almost an inch fell at Strevell, Idaho." (Gunther, 1979a.) In the San Joaquin valley, 95 percent of the drying raisins were spoiled for a loss of 300 million dollars. Norman was followed by Olivia (September 20-23, 1978), Paul (September 23-26, 1978), Rosa (October 2-7), and Sergio (October 18-20), with none moving very far north.

After receiving the watery remnants of three tropical cyclones in three successive years, southern California had none in 1979. What subsequent years will bring cannot be forecast, except by extrapolating the past.

X. CONCLUSIONS

Tropical cyclones are shown, by the present survey of the past 80 years, to be a constant threat to southern California in late summer and early autumn. The first such storm to be documented brought rains to the Colorado desert in 1906, and a previously unknown storm was found to have drenched central California in 1910. Many others probably occurred during that decade, and earlier, but available reports from the ocean southwest of California and from northwest Mexico are not adequate to identify them.

For example, an offshore tropical storm probably was at least a contributing factor to the unusually heavy rains, exceeding four inches in the Sierra Nevada and the mountains of Santa Barbara county on September 22-26, 1904 (Figure 16). But the only information about the storm is that "a disturbance of moderate energy moved southward along the coast to California, causing general rain throughout the [North Pacific] district..." (Wollaber, 1904.) "A well-defined storm covered the [South Pacific] district from the 22nd to the 25th causing rain and numerous thunderstorms throughout California and Nevada. The rain was abnormally heavy in northern California", where San Francisco received 5.07 inches, almost five times the previous September record, and streets and basements were flooded, Willson (1904) said. "Thunderstorms were more severe and frequent than usual in all parts of the state", McAdie (1904) added. "Heavy snow fell in the high Sierra. Grapes, beans, grain in sacks, and unprotected hay were quite seriously damaged by rain." The rainfall pattern, heavy in the mountains (Yosemite 7.09 inches) and Santa Cruz county (Boulder Creek 9.10, Laurel 8.13 inches) and especially Santa Barbara county (Pine Crest 10.95, Santa Barbara 7.15, Santa Maria 4.61) is suggestive of onshore tropical flow.

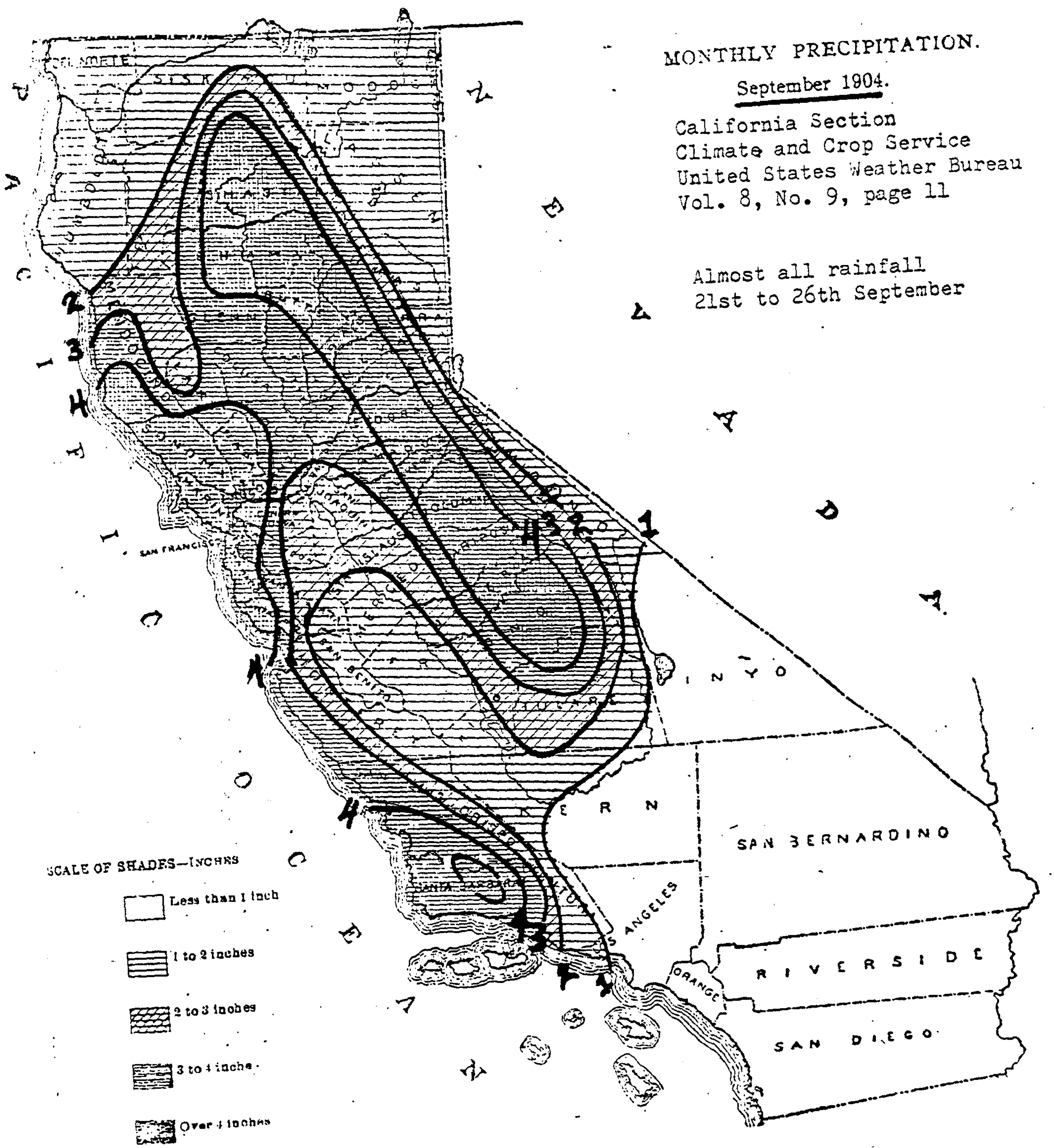

Figure 16. Monthly precipitation, California, September 1904. (From California Section, Climate and Crop Service, Vol. 8, No. 9, p. 11.)

But ship reports are too fragmentary to show any offshore storm during the preceding week, although a meandering low-pressure center is indicated on the Northern Hemisphere maps from August 23 to September 6, a thousand miles south of Santa Barbara.

At irregular intervals, remnants of tropical storms drift into the state, from either the Sea of Cortez or the Pacific side of Baja California, bringing heavy rains which can cause flash floods and widespread destruction. However, these storms and especially those that don't come near enough to cause major damage are also a blessing. They import tropical moisture to bring welcome rains to the deserts, mountains, and even the coastal plains.

Although such storms were charted by Redfield 130 years ago, their very existence was denied by official sources until around 1920. By then increased radio reports from ships sailing just off the Mexican west coast, en route from the newly opened Panama Canal to California and points north and west, left no doubt that the eastern north Pacific ocean had hurricanes as severe as those of the Atlantic or western Pacific.

In the past 30 years, more detailed reporting by military and merchant ships and aircraft reconnaissance flights along with increasing frequency and precision of satellite information have provided a dramatic increase in the number of tropical cyclones reported in the eastern north Pacific. After three decades of studying these storms, Hurd (1941) estimated their average annual number as 5.7 of which 2.2 were hurricanes. A succession of surveys (Table 2) from 1947 onward found larger and larger numbers so that the average number now is around 15, of which perhaps 7 are hurricanes. Now the eastern north Pacific is called the "second most active tropical storm area in the world" (Frank, 1978), rather than a region in which none occurred as maintained 60 years earlier. (Figure 17.)

According to Frank (1978), Director of the National Hurricane Center in Miami, three-fourths of these storms regenerate from circulations that formed initially on the African coast and crossed the Atlantic, Caribbean, and Central America. Earlier, Fendell (1974, p.7) estimated that "half the disturbances over the tropical North Atlantic can be" traced to "the mountainous east African bulge". In turn, he said, half of these "can then be traced across Central America to the eastern Pacific. Actually 75% of eastern Pacific storms originate east of Central America". The region of most rapid development--or redevelopment--of tropical cyclones (Figure 18) is about 500 km due south of Acapulco (Clark, 1978).

In the past 75 years, at least 35 tropical cyclones have either entered southern California or supplied vast quantities of moist air to cause heavy rains there. This account leads to a crude estimate of an almost even chance that southern California, in any given year, will be in some way significantly affected by a tropical cyclone.

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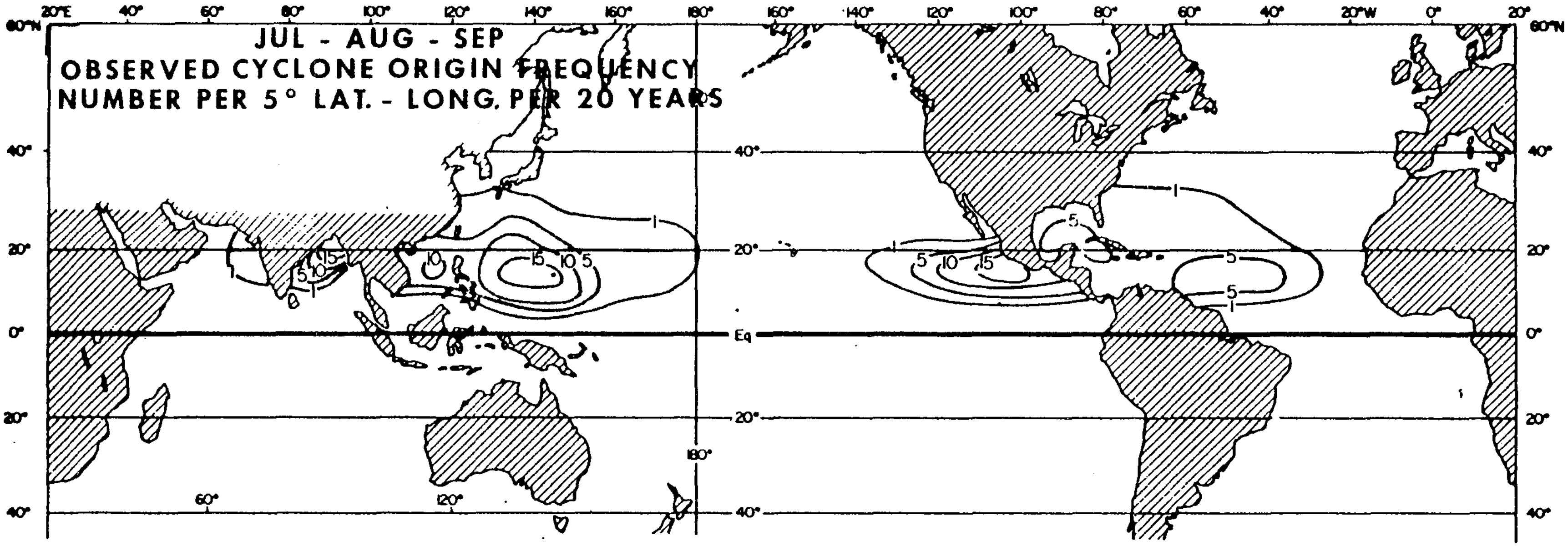

Figure 17. Observed frequency of cyclone origins, 20 years. (From Gray and Frank, NAVENFPREDRSCHFAC TR 78-01, June 1978.)

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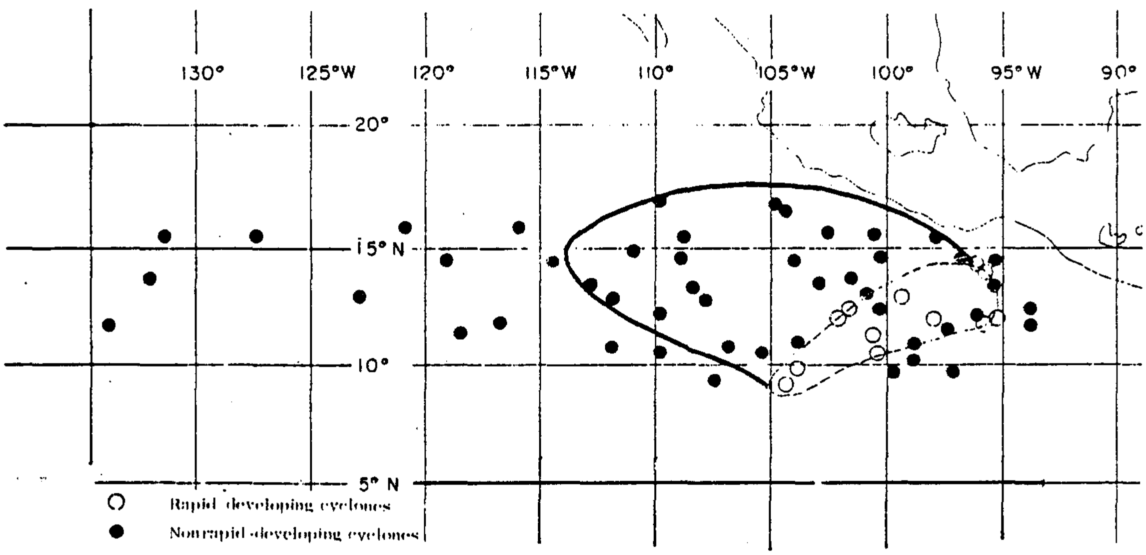

Figure 18. Hurricane development regions, eastern north Pacific, 1973-1976. (From Clark, <u>Mariners Weather Log</u>, 22:325-327, 1978.)

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