NOAA TECHNICAL MEMORANDUM
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1985-1998 NORTH PACIFIC TROPICAL CYCLONES IMPACTING THE SOUTHWESTERN UNITED STATES AND NORTHERN MEXICO: AN UPDATED CLIMATOLOGY

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National Oceanic and Atmospheric Administration
National Weather Service

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1985 - 1998 EASTERN NORTH PACIFIC TROPICAL CYCLONES IMPACTING THE SOUTHWEST UNITED STATES AND NORTHERN MEXICO : AN UPDATED CLIMATOLOGY

Abstract

Tropical systems impacting the southwestern United States are not as uncommon as one might initially think, and their effects throughout this region of the country have been documented by several authors. In 1986, a comprehensive record of effects of tropical cyclones on the southwest United States was published which documented impacts of 84 eastern north Pacific tropical cyclones from 1900 to 1984. This paper will reintroduce those systems by primarily showing the tracks and provide a more in-depth description of additional tropical systems which have affected the area during the period from 1985 to 1998. During the 1900 - 1998 period, the frequency of tropical cyclones impacting the southwest continues to be about 1 per year, although 2-3 are more likely to affect the area during an El Niño year. Both strong El Niño episodes of 1982-83 and 1997-98 spawned an increase in tropical cyclones with impacts to the southwest. In 1997 three tropical cyclones made themselves known with help from a much more aggressive media base throughout southern California and Arizona. By 1998, the frequency of tropical cyclones which increased the moisture supply over the southwest was again above normal. Knowledge of tropical cyclone periodicity through use of ocean-atmosphere links to the El Niño phenomena may in itself be beneficial to water resource planners and emergency managers throughout the southwest.

1. Introduction

In their book on hurricanes, Simpson and Riehl (1981) wrote about tropical cyclones throughout the world's oceans, but placed much of their emphasis on the Atlantic Ocean. They surmised that many hurricanes that form in the eastern Pacific are of Atlantic origin which cross into the Pacific and track northwest or north along the Pacific coast until they encounter the cold California current and die. Waters along the California coast are chilled by up-welling effects and are normally found to be several degrees below 20°C, which is too cold to sustain any development of a tropical system, and an excellent source area for the dissipation process of any tropical cyclone that ventures into these chilled waters. These below 20°C coastal water temperatures are normally well below the 26°C to 27°C oceanic surface temperatures that must be present in order to sustain the life of a tropical cyclone.

With such cold oceanic temperatures protecting the west coasts of California, impacts from tropical systems become less focused on hurricane force winds, since threatening hurricanes or tropical storms quickly loose their strength within 80-100 miles of the coastal areas. Southern California actually experiences stronger wind conditions which result in millions of dollars in damage from the well known "Santa Ana" events that produce hurricane force winds mainly in the fall and winter seasons, and can persist as long as 6 days. Thus, winds of less than 50 miles per hour that result from dissipating tropical cyclones are not seen as a significant threat, especially when compared to Santa Ana winds which blow much stronger and for a longer period of time.

Tropical systems that have affected California in the past however, can and do result in excessive heavy rainfall which results in localized flooding. Tropical storms often play an important role for the climate of southern California, especially during the month of September. Storm track history has shown that during this time of year, tropical cyclones tend to be pulled more northward and recurve northeast and east when strong upper troughs extend deep into the low latitudes. It is during these synoptic conditions that the southwestern United States braces for tropical influences which are capable of producing very heavy rainfall.

Hurricanes Linda and Nora are some of the recent rare tropical systems that created much media attention throughout the southwestern United States during September 1997. Hurricane Linda was a false alarm but was beneficial in triggering an awareness of real threats which can exist from tropical systems over the California coast. Although several remnants of hurricanes have threatened the area, Hurricane Olivia in September 1982 was perhaps the last to dump significant rainfall from the southern mountains north into the Sierra Nevada Mountains. In the early 1990s, other hurricanes moved into locations to the southwest and west of California and their moisture was advected northeast sufficiently to result in issuance of flash flood watches and warnings.

Events which directly impact the area with potential direct strikes are rare, and it was therefore fortunate in 1997 that the media and general public focused on Hurricane Linda, the tropical system which set the stage for more significant events that followed with Hurricane Nora.

2. Data Sources

The data for this paper was taken from several sources. Climatological data of hurricane tracks was retrieved from archives from the Tropical Prediction Center in Miami from their CD ROM "1988-1996 Eastern Pacific Hurricane Archives", and from University archives and plots of tracks (Purdue University). Published information from Weatherwise and Mariners Weather Log for the years before 1988 was also used.

Additionally, information taken from the monthly Storm Data publication, and also from local storm reports was incorporated into the individual histories of the tropical systems from 1985 to 1997. Station archives of products issued and local climatological data sets of precipitation were incorporated when available.

Also reviewed were detailed sea surface temperature (SST) charts which were produced by the National Weather Service in Monterey. Other SST charts used were from NWS archives or from Scripps and CoastWatch.

Hurricane Nora in 1997 occurred shortly after new technologies had been in place at modernized National Weather Service offices. Data sets from radar and satellite, ALERT sites, and improved model guidance were used to describe the synoptic scenario for this system.

Criteria used for selection of events was mainly precipitation based. The tropical system either impacted a large area with some precipitation or a smaller region but with substantial rainfall amounts recorded at several locations.

3. Historical Events: 1900 - 1984

Court (1980) was one of the first authors to identify the impact of tropical cyclones on the climate of the southwestern United States. In his paper, he provided a history of some of the most notable tropical cyclone tracks, concluding that they are a constant threat to southern California in late summer and early autumn.

Also looking at the frequency of tropical cyclones to impact the southwestern United States was Smith (1986), who wrote that nearly every year an eastern north Pacific tropical cyclone will move into a favorable position for upper level winds to bring clouds and moisture from the cyclone over the southwest to produce showers and thunderstorms. According to his research, these situations occur as early as June or as late as October, with September being the most likely month for a tropical cyclone to have an effect on the weather in the southwestern United States. As a rule, the winds are rarely a factor, but the tropical moisture that is imported into the area results in heavy precipitation that can, and often does, produce flash flooding in orographically favored areas.

Figure 1 shows the monthly distribution of eastern north Pacific tropical cyclone events that have affected the southwest U.S.

Totals used to depict this monthly distribution were taken from Smith's paper. His data vividly shows the bias for occurrence of a September event.

The graph includes tropical cyclones that had some impact on the southwest U.S. during the period from 1900 - 1984. This trend continues, as East North Pacific tropical cyclones have generated more September events that affect the southwest through 1998.

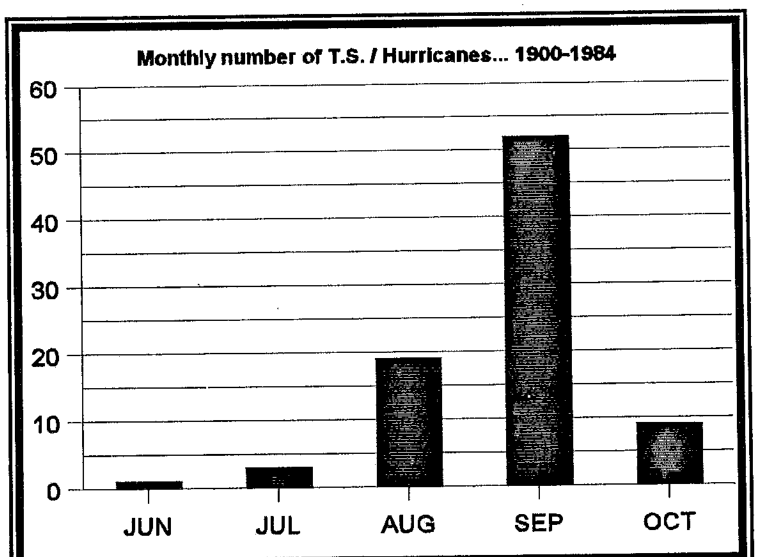


Figure 1 ..... Tropical storms / hurricanes impacting the southwest during the period from 1900 - 1984: June = 1; July = 3; August = 19; September = 52; October = 9.

Appendices A - K provides the 84 tropical cyclone tracks that impacted the southwestern United States during the 1900 - 1984 period. Note that many of the storms made direct hits on southern Baja California. Although the majority never reach the southwestern U.S., it is the moisture of the decaying system that normally gets caught up in favorable atmospheric trajectories which transport the rich tropical moisture into California and Arizona.

However, it should also be noted that not all systems that approach the southwest affect the area, and that critical factors such as steering and resident thermodynamic parameters are extremely important for advection and release of the tropical moisture.

A quick look at some of the most memorable August and September tropical cyclones which have impacted California and Arizona include:

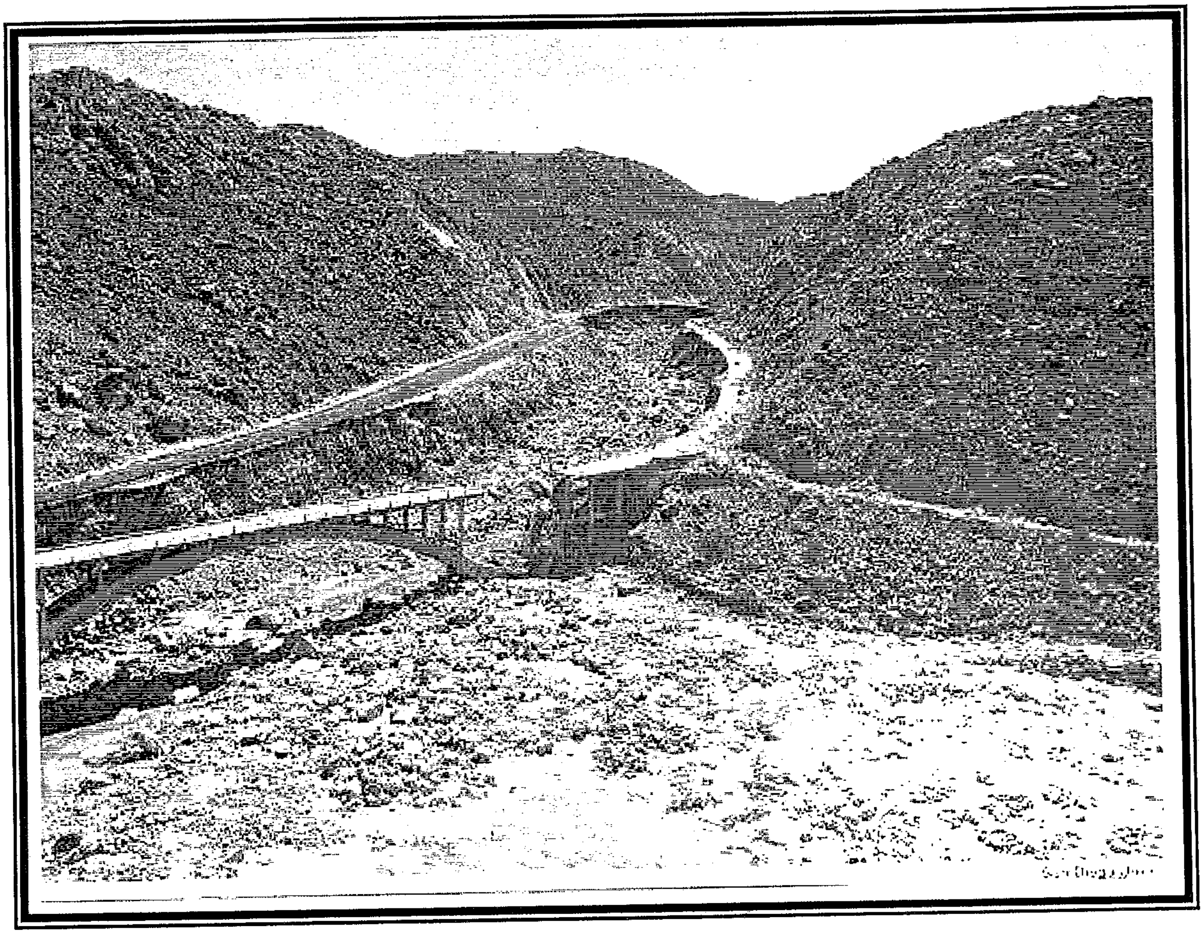
- Tropical Storm Katherine (September 17-19, 1963). This tropical storm was not detected until it was about 200 miles southwest of San Diego. The track on Appendix G shows the movement to the northeast making landfall in northern Baja California near 30.5°N and 116°W. It produced rainfall of 6 to 6 ½ inches in the central and southern mountains of Southern California on September 17-19, and 2 to 2 ½ inches in Arizona . It occurred during the El Niño of 1963-64.

- Tropical Storm Katrina (August 31, 1967). Unique in that it moved from near the southern tip of Baja California, northward parallel to the east coast along the Gulf of California entering the U.S. on the Arizona side of the California/Arizona border. The track is shown in Appendix H. Katrina destroyed half of the town of San Felipe with torrential rains and high waves generated by winds of just under 100 mph. Rainfall amounts in Arizona and southern California were generally a little over 2 inches but Wellton, Arizona did receive just under 5 inches from this storm. This was not associated with an El Niño year.

- Tropical Storm Hyacinth (September 3-6, 1972). This was the first tropical cyclone to move over southern California since September 1939 when a tropical cyclone took a similar track and entered in the same general area between Los Angeles and San Diego. The track is shown in Appendix H. Only light showers were reported with this system and maximum rainfall amounts recorded over the southern California mountains were generally just over half an inch. This occurred during the El Niño of 1972-73.

- Tropical Storm Kathleen (September 9-12, 1976). This was perhaps the worst tropical storm to affect southern California. The track which caused record rains and tremendous crop damage is shown in Appendix H. The hardest hit area was the small desert community of Ocotillo in Imperial County. Flood waters tore homes from their foundations and left nearly 70 percent of the town buried in sand which measured up to 10 feet in depth. The raging flood waters poured through a normally dry canyon wiping out a bridge on U.S. Highway 80 and undermining Interstate 8. This occurred during the El Niño of 1976-77.

A photograph taken by the Union Tribune newspaper shows the destruction of a stretch of highway left behind after Kathleen moved through southern California.



- Tropical Storm Doreen (August 16-17, 1977). In just under a year, the unlikely event of a second tropical storm occurred in the same general region of southern California. The track is shown in Appendix I. Doreen dumped 4.5 inches of rain within several hours in the Salton Sea area of Imperial County. The heavy rainfall flooded 300 homes, causing 4 million dollars in property damages and 9 million dollars in crop damage. This occurred during the El Niño of 1976-77.

- During the strong El Niño of 1982-83, seven (7) tropical cyclones (Norman, Olivia, Paul, Manuel, Octave, Priscella, and Tico) affected the southwest United States. Most produced localized rainfall of 1-3 inches with the exception of "Octave", which produced a pocket of 6-9 inches of rainfall over the southeast third of Arizona. Serious flooding occurred on most streams and rivers in southeast Arizona, with peak flows established on several large rivers. Many towns and communities suffered extensive damage but Clifton and Marana (north of Tuscon) were devastated. The tracks of these are found in Appendix J and Appendix K.

4. Historical Data Updated

This section will list the tropical systems which have impacted the southwestern states of California, Arizona, New Mexico, and also northern Mexico. Emphasis on effects to these areas is for southern California but descriptions of impacts to areas such as Mexico and other southwestern states will also be included.

	Name	Month / Date(s)	Year
A.	Hurricane Terry	September 15-24	1985
B.	Hurricane Ramon	October 5-12	1987
C.	Tropical Storm Selma	October 27-31	1987
D.	Hurricane Octave	September 8-16	1989
E.	Hurricane Raymond	September 25 - October 5	1989
F.	Hurricane Boris	June 2-8	1990
G.	Hurricane Odile	September 23 - October 2	1990
H.	Tropical Storm Rachel	September 27 - October 3	1990
I.	Tropical Storm Hilda	August 8-14	1991
J.	Hurricane Lester	August 20-24	1992
K.	Hurricane Hilary	August 17-27	1993
L.	Hurricane Ismael	September 12-15	1995
M.	Hurricane Fausto	September 10-14	1996
N.	Tropical Storm Ignacio	August 17-19	1997
O.	Hurricane Linda	September 9-17	1997
P.	Hurricane Nora	September 16-26	1997
Q.	Tropical Storm Frank	August 6-9	1998
R.	Hurricane Isis	September 1-3	1998

Table 1. East North Pacific Tropical Cyclones which impacted the southwest U.S. from 1985 - 1998.

Table 1 provides a listing of the tropical cyclones that impacted California, Arizona, New Mexico or northern Mexico during the 1985-1998 tropical cyclone seasons. Tracks for these are shown with each individual event write-up, and are also included in Appendices L through N. The data continues to show that although strong impacts from a major hurricane are rare over the southwest United States, the orientation of the upper level flow plays a critical role in production of rainfall which can result in flooding and adverse impacts over southern California, Arizona, and New Mexico.

A. Hurricane Terry ..... September 15 - 24, 1985

The 1985 hurricane season was an above normal year for tropical cyclones over the eastern north Pacific. Using the latest 30 year period, the Tropical Prediction Center in Miami indicates that the average number of tropical cyclones that form in the eastern north Pacific is fourteen (14).

Figure 2 shows the track of Hurricane Terry.

Gunter (1986) stated that in 1985, a total of 25 cyclones formed, one less than the record set in 1982. Eleven (11) of these intensified to hurricane strength and a total of twenty-two were intense enough to be named.

Although only one (Hurricane Waldo) moved onshore, crossing the Mexican Coast with 90 knots of wind 110 nautical miles northwest of Mazatlan, it was Hurricane Terry that affected the southwest even before drifting to near latitude 20°N where some of Terry's moisture was pulled northward into the southwest portion of the United States.

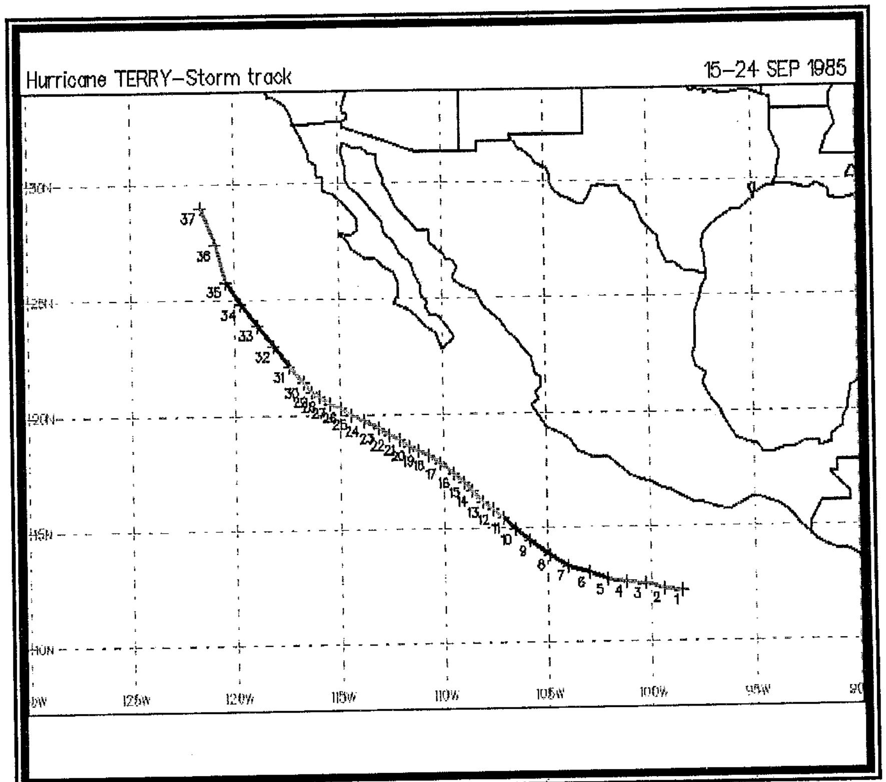


Figure 2 **T.D.** (1-4) Sep. 15/18Z-16/12Z; **T.S.** (5-10) Sep. 16/18Z - 18/00Z; **HUR** (11-30) Sep. 18/06Z - 23/00Z; **T.S.** (31-34) Sep. 23/06Z-24/00Z; **T.D.** (35-37) Sep.24/06Z-24/18Z.

During its early life cycle when it was located in the deep tropics near latitude 16°N and longitude 108°W on September 19, 1985, surface features over the United States included a weak frontal system extending southwest through central Colorado and New Mexico. Dew point temperatures ahead of the frontal boundary were in the lower to middle 60s, as tropical low level moisture had already worked its way north of Hurricane Terry's location. Terry's main moisture core never did reach the southwest, but instead, it was the pre-storm tropical moisture which interacted with the frontal system when the hurricane was still south of the southern tip of Baja California that fed storms in Arizona.

At the 500 mb level, an upper low located west of central California had a trough which extended south to about 25°N with strong southwest winds of 45-55 knots over most of California, Arizona, and Nevada. Widespread precipitation of half an inch to nearly three quarters of an inch occurred on September 19th with this weak frontal system which had tapped moisture from Hurricane Terry.

Storm Data (1985) entries for Arizona indicated that heavy rains and plugged drains that fed Chase Creek in Clifton (Greenlee County) caused 5 homes and several businesses along U.S. 666 to flood. Boulders and other debris were washed down, with 9 separate rock slides reported. One liquor establishment reported 6 inches of mud on the floor. In southeast Arizona, a series of very large thunderstorms moved aross much of Gila, Pinal, and Pima Counties. In California, the tropical moisture produced rainfall that washed out several roads in Eastern Riverside County in the North Shore area near the Salton Sea.

Terry began to turn north on September 22, thereby creating alarm for Baja California and southwestern United States. However, as it moved over colder waters, it rapidly dissipated approximately 300 miles southwest of San Diego, California. As the remnants of Terry approached 25°N and 120°W on September 24, the upper flow had changed to a strong northwest flow, thereby diverting all tropical moisture away from the southwestern portion of the United States. Figure 3 shows the satellite photograph of Hurricane Terry on September 19, 1985 .

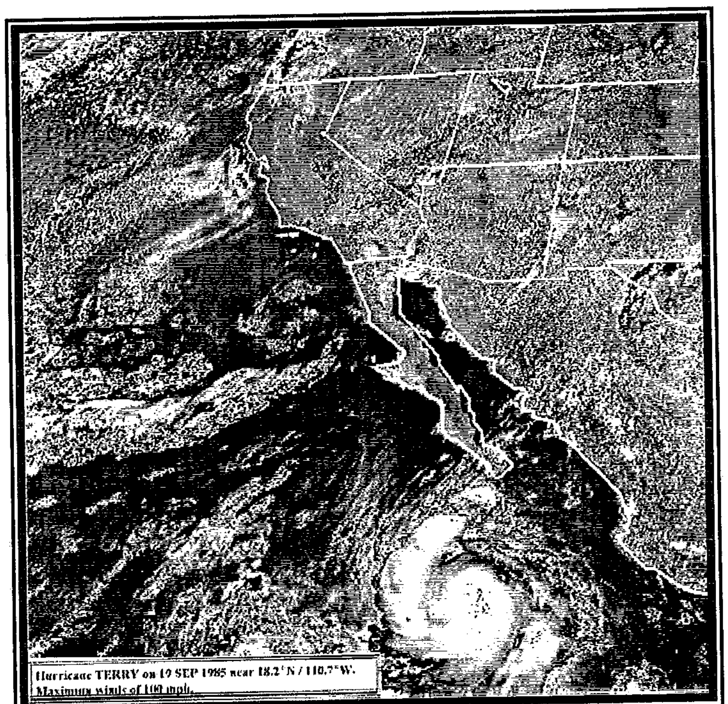


Figure 3 - Hurricane Terry on September 19, 1985

The best track for Hurricane Terry can be found in Table 1985-A. All latitude and longitude points in this table begin with the date when the tropical cyclone was in the vicinity of 15°N.

TABLE 1985-A
BEST TRACK FOR HURRICANE TERRY

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 18/0000	14.9 N	106.5 W	-	55	T.S.
/0600	15.4 N	107.1 W	-	65	HURRICANE
/1200	15.8 N	107.6 W	-	70	HURRICANE
/1800	16.1 N	108.1 W	-	75	HURRICANE
SEP. 19/0000	16.6 N	108.6 W	-	90	HURRICANE
/0600	17.0 N	109.0 W	-	90	HURRICANE
/1200	17.4 N	109.5 W	-	90	HURRICANE
/1800	17.8 N	110.1 W	-	95	HURRICANE
SEP. 20/0000	18.2 N	110.7 W	-	100	HURRICANE
/0600	18.4 N	111.2 W	-	95	HURRICANE
/1200	18.6 N	111.6 W	-	90	HURRICANE
/1800	18.9 N	112.1 W	-	90	HURRICANE
SEP. 21/0000	19.1 N	112.6 W	-	90	HURRICANE
/0600	19.4 N	113.1 W	-	100	HURRICANE
/1200	19.7 N	113.8 W	-	90	HURRICANE
/1800	20.0 N	114.4 W	-	80	HURRICANE
SEP. 22/0000	20.3 N	114.9 W	-	80	HURRICANE
/0600	20.5 N	115.4 W	-	80	HURRICANE
/1200	20.8 N	115.9 W	-	75	HURRICANE
/1800	21.0 N	116.3 W	-	75	HURRICANE
SEP. 23/0000	21.4 N	116.7 W	-	65	HURRICANE
/0600	22.1 N	117.4 W	-	60	T.S.
/1200	23.0 N	118.1 W	-	55	T.S.
/1800	23.9 N	118.9 W	-	45	T.S.
SEP. 24/0000	24.8 N	119.7 W	-	40	T.S.
/0600	25.8 N	120.4 W	-	30	T.D.
/1200	27.4 N	120.9 W	-	25	T.D.
/1800	29.0 N	121.6 W	-	25	T.D.

NOTE: All latitude and longitude points in this table begin with the date when the tropical cyclone was in the vicinity of 15°N.

The following year, 1986, proved to be fairly inactive as the cluster of tropical cyclone activity developed between latitude 10°N and 16°N, with the majority of the systems tracking in a westerly direction and only a slight drift to the north occurring mainly after they crossed longitude 120°W. The satellite photograph on Figure 4 shows a family of tropical cyclones which were tracking west. Again, shearing effects can contribute to moisture advection into the southwest as is clearly seen with Tropical Storm Madeline which was at least 750 miles southwest of San Diego.

According to Gunther, et al. (1987), impacts to Baja California were from Hurricane Newton, which passed within 25 miles of Cape Pulmo which is located to the northeast of Cabo San Lucas, and from the moisture streaming northeast from Tropical Storm Madeline into northern Baja California. Both impacted Baja on September 22, 1986 as shown in the satellite photograph on Figure 4.

However, no significant rainfall or other impacts were felt over any areas of the United States.

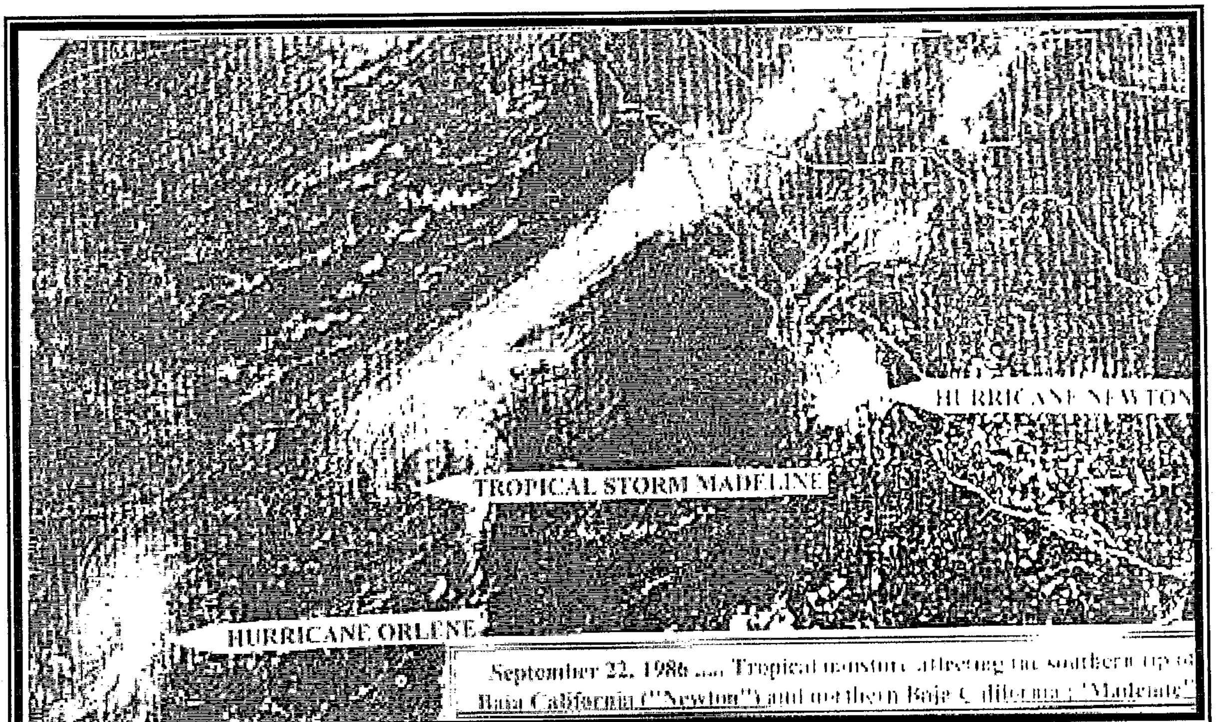


Figure 4 ..... 1986 Tropical cyclone season in the Eastern North Pacific showing moisture streaking northeast from Tropical Storm Madeline into northern Baja California.

B. Hurricane Ramon ..... October 5-12, 1987

While some tropical cyclones result in damage due to heavy rains, Ramon's moisture was welcomed in particular over the Mt. Palomar, California area for its rainfall which helped extinguish a week-long brush fire. Hurricane Ramon was another one of those systems which provided a stream of rich tropical moisture to southern California on October 11, 1987 even though the center of the hurricane remained well to the south southwest of San Diego, California.

Figure 5 shows the track of Hurricane Ramon.

Sea surface temperatures during 1987 were favorable for rapid development of the tropical disturbance into a strong hurricane. By October 5th, Ramon had moved into an area where the water over the ocean surface was 28°C. It intensified to hurricane strength on October 7th and was pulled northward by an upper level trough which had a Low centered near 35°N and 135°W.

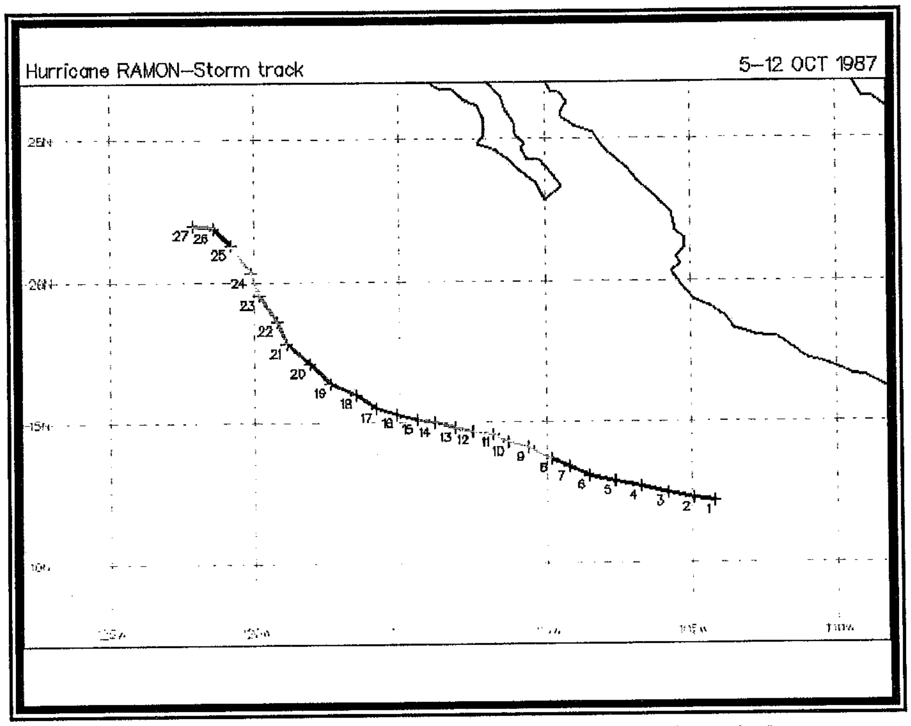


Figure 5 ... **T.S.** (1-7) Oct. 5/18Z-7/06Z; **HUR** (8-24) Oct. 7/12Z-11/12Z; **T.S.** (25) Oct. 7/18Z; **T.D.** (26-27) Oct. 12/00Z-06Z.

Surface features on October 9-11 over the southwest were depicting a weak thermal low along the California and Arizona border. At the 500 mb level, a closed low was quasi-stationary near 35°N and 130°W during that same 3 day period. Mid level winds to the north of Hurricane Ramon increased to a steady 40-45 knots by October 11. As it encountered these winds, shearing occurred and Ramon weakened rapidly. The effects of shearing and its track over colder waters were sufficient to create its quick demise. However, its moisture was transported by the strong mid level flow into California where significant rainfall occurred.

Precipitation amounts with Hurricane Ramon over most of southern California ranged from close to three quarters inch along the coast to one and a half to two inches over the mountains from the rains on October 11th and 12th.

At San Diego Lindbergh Field, .51 inches of rain fell on October 11 and .18 inches on October 12 for a total of .69 inch, which is a little over twice the amount of normal rainfall of .33 inch for the entire month. During the same two day period, North Island NAS recorded a total of .89 inch, and Camp Pendleton recorded 2.14 inches. Normal daily rainfall for any day during the month of October is generally .02 inch or less for these locations. Similar rainfall amounts of one inch to one and a half inches of rain were recorded over extreme northern Baja California.

The satellite photograph shows a very impressive moisture band which extended from the northern portion of Hurricane Ramon, northeastward.

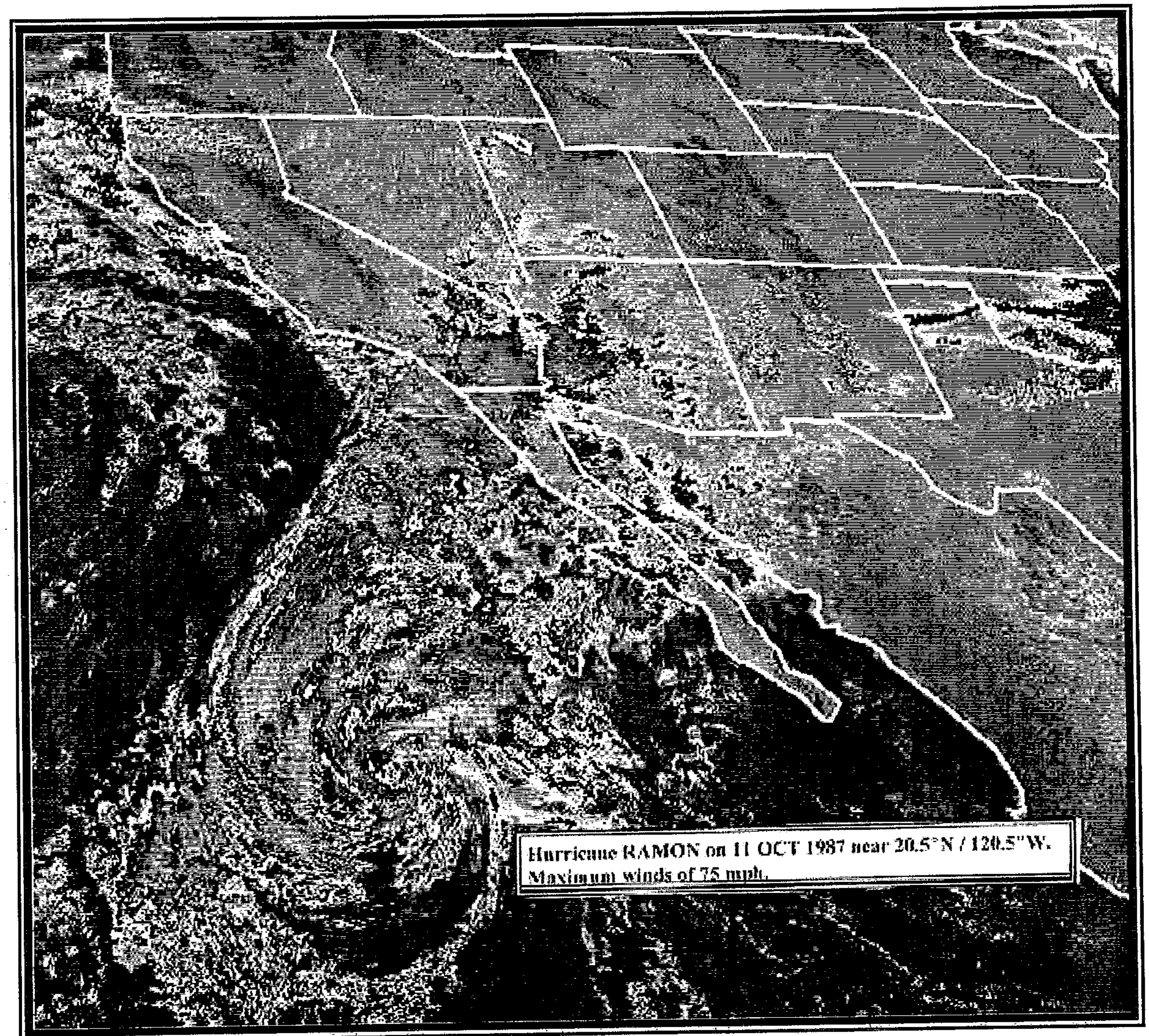


Figure 6 Hurricane Ramon with moisture spreading northeast into southern California on October 11, 1987.

In southern California, heavy rain produced street flooding along the coast, dozens of traffic accidents through all areas, and mud slides in the burn areas of the mountains. The traffic accidents resulted in numerous injuries. Rainfall in the city of Ramona was so heavy that it sprung a leak in the roof of the city library resulting in damage to books. In Orange County, several streets were closed due to high water on the roadways.

The best track for Hurricane Ramon can be found in Table 1987-A. The table provides the latitude and longitude points, maximum winds in knots, and the category at each time listed.

TABLE 1987-A
BEST TRACK FOR HURRICANE RAMON

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
OCT. 05/1800	12.2 N	104.2 W	-	35	T.S.
OCT. 06/0000	12.3 N	104.9 W	-	35	T.S.
OCT. 07/0000	13.1 N	108.5 W	-	35	T.S.
/1200	13.7 N	109.8 W	-	65	HURRICANE
OCT. 08/0000	14.3 N	111.3 W	-	80	HURRICANE
/1200	14.7 N	112.5 W	-	95	HURRICANE
OCT. 09/0000	15.0 N	113.8 W		110	HURRICANE
/0600	15.1 N	114.4 W	-	120	HURRICANE
/1200	15.3 N	115.1 W	-	120	HURRICANE
/1800	15.5 N	115.8 W	-	120	HURRICANE
OCT. 10/0000	16.0 N	116.5 W	-	120	HURRICANE
/0600	16.4 N	117.4 W	-	115	HURRICANE
/1200	17.1 N	118.1 W	-	115	HURRICANE
/1800	17.8 N	118.9 W	-	110	HURRICANE
OCT. 11/0000	18.6 N	119.2 W	-	100	HURRICANE
/0600	19.5 N	119.8 W	-	80	HURRICANE
/1200	20.3 N	120.1 W	-	75	HURRICANE
/1800	21.3 N	120.8 W	-	45	T.S.
OCT. 12/0000	21.9 N	121.4 W	-	25	T.D.
/0600	22.0 N	122.1 W	-	20	T.D.

C. Tropical Storm Selma ..... October 27 - 31, 1987

Selma, a rather weak tropical system, demonstrated that intensity does not necessarily mean more rainfall for the southwest. This system had a very short life span, becoming a tropical depression on October 27th near latitude 10°N and longitude 121°W. The system then fluctuated from tropical depression to tropical storm for the next few days, as it fought to keep its strength over colder waters.

Figure 7 shows the track of Tropical Storm Selma.

Tropical Storm Selma never did get a chance to get fully organized as it tried to survive in an area where water temperatures were not favorable for rapid growth.

After developing and taking a very brief jog to the northwest, it began to track in a more northerly direction and by October 30th it had curved to the northeast and quickly lost its strength as it traveled over colder waters.

On October 30th, it was downgraded to a tropical depression and began to move to the northeast, finally dissipating completely in an area around 600 miles southwest of San Diego, California on October 31st.

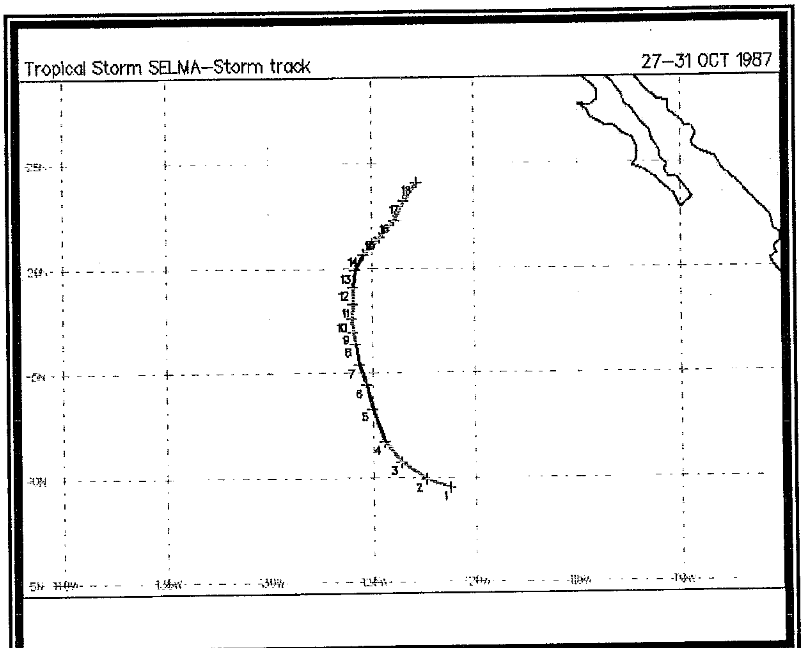


Figure 7 ... T.D. (1-3) Oct 27/00Z -12Z; T.S. (4-7) Oct 27/18Z - 28/12Z; T.D. (8-11) Oct 28/18Z-29/12Z; T.S. (12-13) Oct 29/18Z-30/00Z; T.D. (14-18) Oct 30/06Z-31/06Z

Satellite photographs of Tropical Storm Selma show a significantly large amount of cloudiness to the north of the system with embedded showers and thunderstorms. As the system moved to the northeast, this convective area pushed into southern California and combined with a surface cold front to produce heavy rainfall.

Figure 8 shows the moisture band from Selma on October 30th located to the southwest of southern California. Figure 9 is for the following day, on October 31st, when widespread rainfall was occurring over the southern half of California and western Arizona.

Tropical Storm Selma was responsible for providing southern California with rainfall amounts well in excess of normal. The heavier rains caused numerous mud slides. Three rock slides occurred in the area of Soledad Canyon Road, one mile west of Acton in northern Los Angeles County. A rock slide blocked the on ramp to the Antelope Valley Freeway (SR-14) between Acton and Canyon Country.

Water flooded the Pacific Coast Highway (SR-1) near Malibu. The water stood seven to nine inches deep at several locations. Standing water was also reported on the Ventura Freeway (US-101) in the San Fernando Valley.

Over half an inch of rain (.51) fell at Lindbergh Field on October 31, while Camp Pendleton received .61 inch, and North Island reported .54 inch.

Three fatalities were reported - all of the deaths were traffic related. Additionally, there were approximately 25 weather related traffic injuries.

Whereas, it was the rich tropical moisture from Selma that was released, a cut off low that had formed off the coast a week earlier, was a major dynamic feature that helped trigger the release of the abundant moisture. As with "Ramon" in 1987, the subtropical jet that developed to the north of "Selma" helped to transport moisture in a dynamically charged jet streak across California.

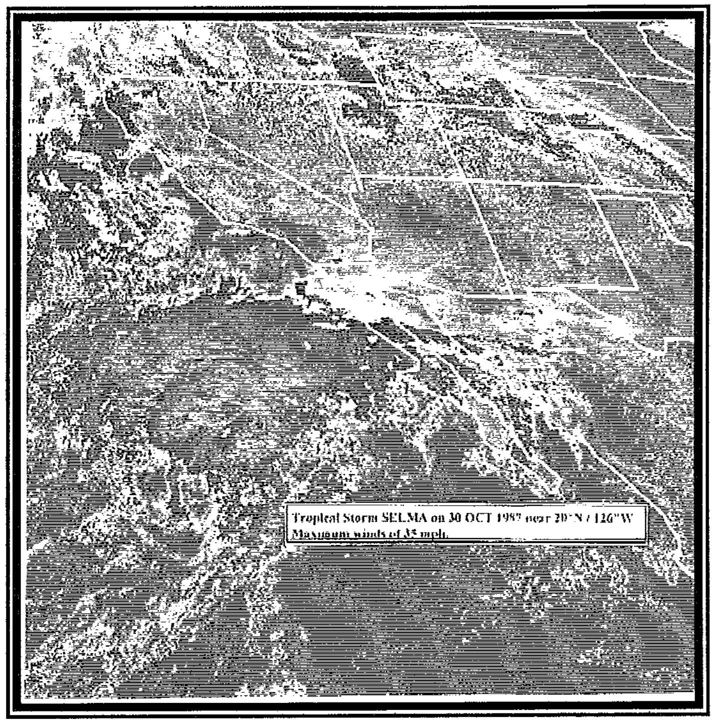


Figure 8 ..... Tropical Storm Selma - October 30, 1989

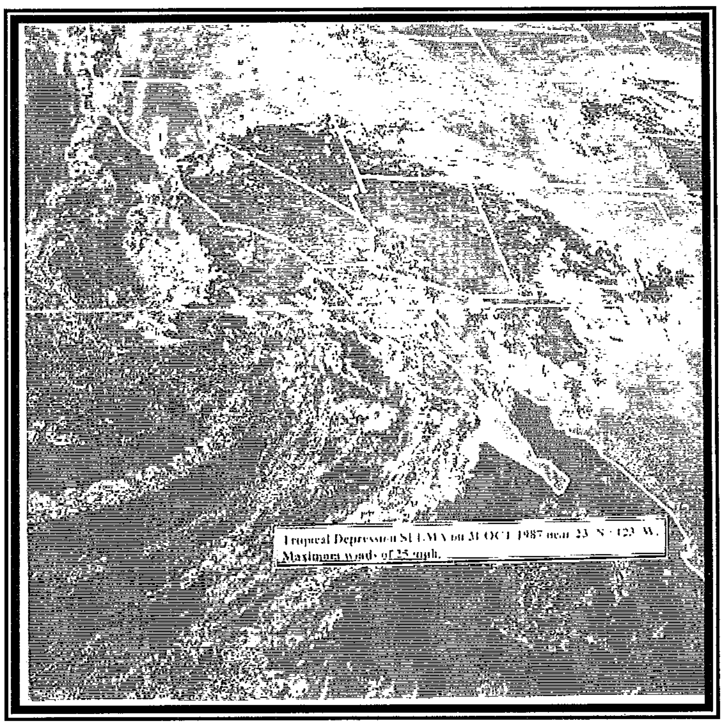


Figure 9 ..... Tropical Storm Selma - October 31, 1989

Over Baja California, satellite pictures indicated bands of showers moving through the central portions also releasing significant moisture - but no reports of rainfall amounts were available from those locations.

The best track for Tropical Storm Selma can be found in Table 1989-A. The table provides the latitude and longitude points, maximum wind speeds in knots, and the category at each time listed.

TABLE 1989-A
BEST TRACK FOR TROPICAL STORM SELMA

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
OCT. 27/0000	09.5 N	121.2 W	-	25	T.D.
/0600	09.9 N	122.4 W	-	30	T.D.
/1200	10.7 N	123.6 W	-	30	T.D.
/1800	11.7 N	124.4 W	-	35	T.S.
OCT. 28/0000	13.3 N	125.0 W	-	35	T.S.
/0600	14.4 N	125.3 W	-	35	T.S.
/1200	15.4 N	125.6 W	-	35	T.S.
/1800	16.4 N	125.8 W	-	30	T.D.
OCT. 29/0000	17.0 N	125.9 W	-	30	T.D.
/0600	17.6 N	126.0 W	-	30	T.D.
/1200	18.3 N	125.9 W	-	30	T.D.
/1800	19.1 N	125.9 W	-	35	T.S.
OCT. 30/0000	19.9 N	125.8 W	-	35	T.S.
/0600	20.7 N	125.4 W	-	30	T.D.
/1200	21.5 N	124.6 W	-	25	T.D.
/1800	22.3 N	123.9 W	-	25	T.D.
OCT. 31/0000	23.2 N	123.4 W	-	25	T.D.
/0600	24.1 N	122.8 W	-	20	T.D.

In 1988, there were a total of 15 tropical systems which formed off the west coast of Mexico between latitudes 10°N and 20°N. However, the steering took all in an almost due westerly track across the Pacific Ocean. Only the remnants of Tropical Storm John approached the extreme southern tip of Baja California on August 20-21, but there was no significant weather that resulted from this system.

D. Hurricane Octave ..... September 8-16, 1989

The 1989 hurricane season was another near normal year for tropical cyclones over the eastern North Pacific. A total of 17 tropical systems formed, nine (9) made it to hurricane strength, with the majority tracking as they did the year before, in a westerly direction. However, two systems (Hurricane Octave and Hurricane Raymond) did impact the southwest, tracking across latitude 25°N and resulting in entrainment of moisture into the southwest.

Figure 10 shows the track of Hurricane Octave.

Hurricane Octave had a life history of just over one week. It developed on September 8th near latitude 11.2°N and longitude 99.9°W and dissipated on September 16th near 28.4°N and 118.1°W, about 250 miles south-southwest of San Diego.

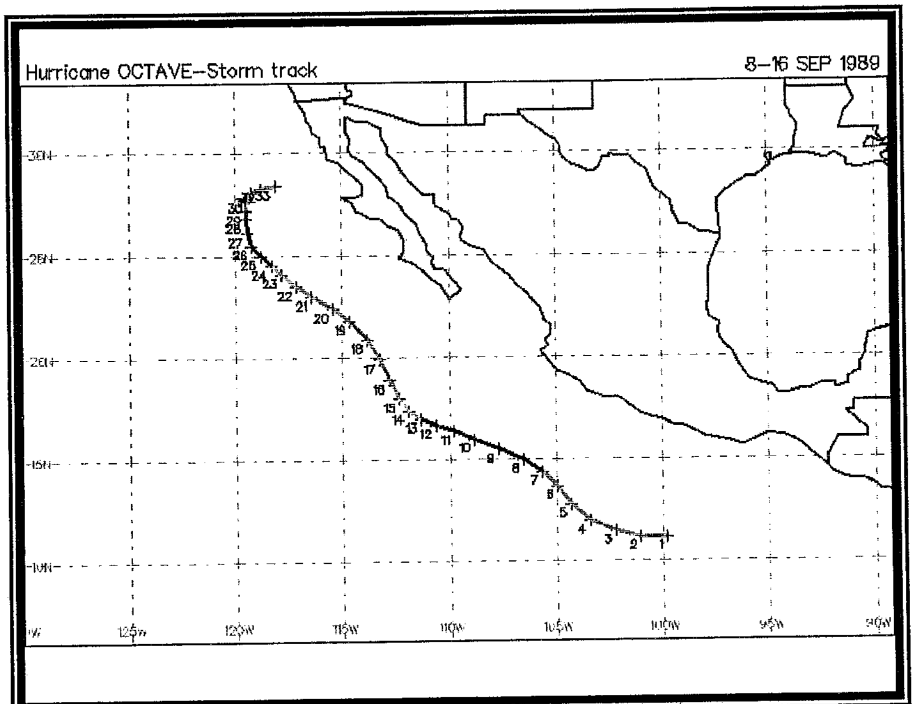


Figure 10 ... **T. D.** (1-6) Sep. 08/18Z - 09/18Z; **T. S.** (7-12) Sep. 10/06Z -11/12Z; **HUR** (13-23) Sep. 11/18Z - 14/06Z; **T. S.** (24-28) Sep. 14/12Z - 15/12Z; **T. D.** (29-33) Sep. 15/18Z - 16/18Z.

As the hurricane tracked northward, an upper level low that had anchored itself about 600 miles west of San Francisco maintained a south and south-southwest flow over most of California. By September 17th, the southwest flow had increased with winds of 45-55 knots across the area and a jet maximum of 70 knots was observed crossing central California near San Francisco.

Lawrence (1990) mentioned that although Octave did not make landfall as a tropical cyclone, its remnants were tracked across southern and central California on September 17th and 18th. These remnants consisted of an extended period of cloudiness and light rain at the height of the dry season. Results were devastating to the grape, raisin and tomato industry with total damage to the agriculture industry approaching $100M in California.

Table 1989-A provides the best track data for Hurricane Octave for each 6-hour synoptic time period. Also provided in the table are the maximum sustained winds for each time period. The table only shows initial genesis area, then all positions after the tropical system reached 15°N latitude.

TABLE 1989-A BEST TRACK FOR HURRICANE OCTAVE					
DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 08/1800	11.2 N	99.8 W	1010	25	T.D.
SEP. 10 /1200	15.0 N	106.5 W	1004	35	T.S.
/1800	15.5 N	107.7 W	1002	40	T.S.
SEP. 11/0000	16.0 N	108.8 W	1000	45	T.S.
/0600	16.4 N	109.8 W	996	50	T.S.
/1200	16.7 N	110.6 W	992	60	T.S.
/1800	17.0 N	111.3 W	985	70	HURRICANE
SEP. 12/0000	17.4 N	111.9 W	975	80	HURRICANE
/0600	18.0 N	112.3 W	965	90	HURRICANE
/1200	18.9 N	112.8 W	955	105	HURRICANE
/1800	19.9 N	113.2 W	950	110	HURRICANE
SEP. 13/0000	20.9 N	113.8 W	948	115	HURRICANE
/0600	21.8 N	114.6 W	950	110	HURRICANE
/1200	22.4 N	115.4 W	955	105	HURRICANE
/1800	23.0 N	116.4 W	968	90	HURRICANE
SEP. 14/0000	23.5 N	117.1 W	977	80	HURRICANE
/0600	24.1 N	117.8 W	985	70	HURRICANE
/1200	24.5 N	118.3 W	990	60	T.S.
/1800	25.0 N	118.8 W	995	55	T.S.
SEP. 15/0000	25.5 N	119.2 W	998	45	T.S.
/0600	26.1 N	119.4 W	1002	40	T.S.
/1200	26.8 N	119.5 W	1005	35	T.S.
/1800	27.2 N	119.5 W	1007	30	T.D.
SEP. 16/0000	27.8 N	119.4 W	1008	30	T.D.
/0600	28.1 N	119.2 W	1009	25	T.D.
/1200	28.3 N	118.8 W	1010	25	T.D.
/1800	28.4 N	118.1 W	1012	20	T.D.

E. Hurricane Raymond ..... September 25 - October 5, 1989

The last tropical system of the East Pacific hurricane season to affect the southwestern portion of the United States in 1989 was Hurricane Raymond. It was also the strongest hurricane that developed, with maximum winds of 145 mph occurring on October 1.

Figure 11 shows the track of Hurricane Raymond.

Surface features showed a weak frontal boundary extending southwest from Las Vegas, Nevada through just east of San Diego, California on October 3rd moving east across Arizona into eastern New Mexico by October 5th.

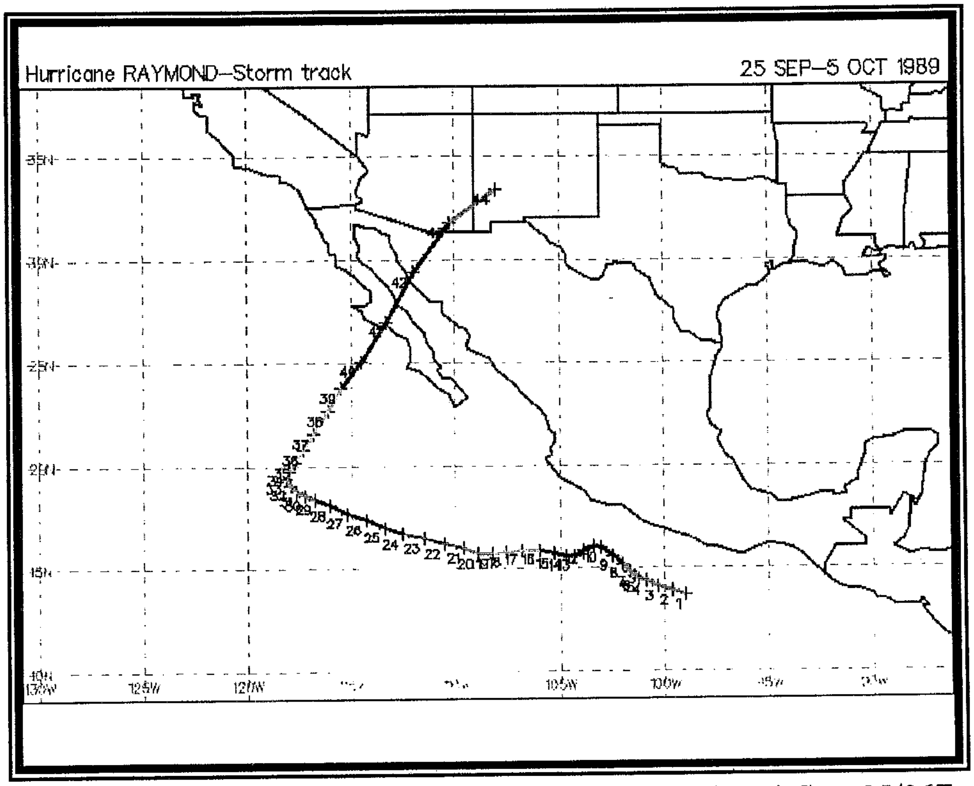


Figure 11 ... **T. D.** (1-7) Sep. 25/00Z - 26/12Z; **T.S.** (8-15) Sep. 25/06Z - 28/12Z; **HUR** (16-38) Sep. 28/18Z - Oct. 04/06Z; **T. S.** (39-42) Oct. 04/12Z - 05/06Z; **T. D.** Oct. 05/12Z-05/18Z.

At the 500 mb level, a strong closed low was located just west of Salt Lake City, Utah on October 3-4, with southwest winds of 45-65 knots analyzed over California, Arizona, and Utah becoming more southerly over southeast Arizona into New Mexico.

Hurricane Raymond was most intense as it approached the southern tip of Baja California. The hurricane recurved on October 3rd and accelerated quickly to the northeast, crossing Baja California near Punta Delgadito. Raymond crossed Baja and entered northwest Mexico along the coast almost due west of Hermosillo, weakening to tropical storm strength. It continued to move rapidly to the northeast into extreme southeast Arizona on October 4th. On October 5th, Raymond now a tropical depression, was moving northeast across extreme southeast Arizona and into New Mexico.

Precipitation from Raymond was light over Mexico as it moved quickly to the northeast. However, with 500 mb winds over northern Baja and Mexico into Arizona and New Mexico being southwest 25-40 knots on October 3 and south and southwest 40-45 knots on October 4, rich moisture from Raymond was quickly transported into Arizona and New Mexico, with flash floods resulting from two to five inches of rain in southeast Arizona.

The heaviest rainfall occurred between Nogales and Duncan. In the vicinity of Willcox, Arizona widespread flooding was reported. Willcox recorded 2.7 inches of rain in a 24 hour period and just north of there, 4.5 inches of rain was reported. About 75% of the community's streets had about 18 inches of water passing over them. Rains ended about 8:30 am on October 5th, but runoff continued all day. Nogales, Arizona also had locally heavy rains, with 2.27 inches reported in the same 24 hour period. Estimated damage to the area as a result of Raymond was $1.5 million.

The satellite photograph on Figure 12 shows Hurricane Raymond as it approached Baja California. Note the extensive tropical moisture band which spread northeast into Arizona around midday on October 4, 1989.

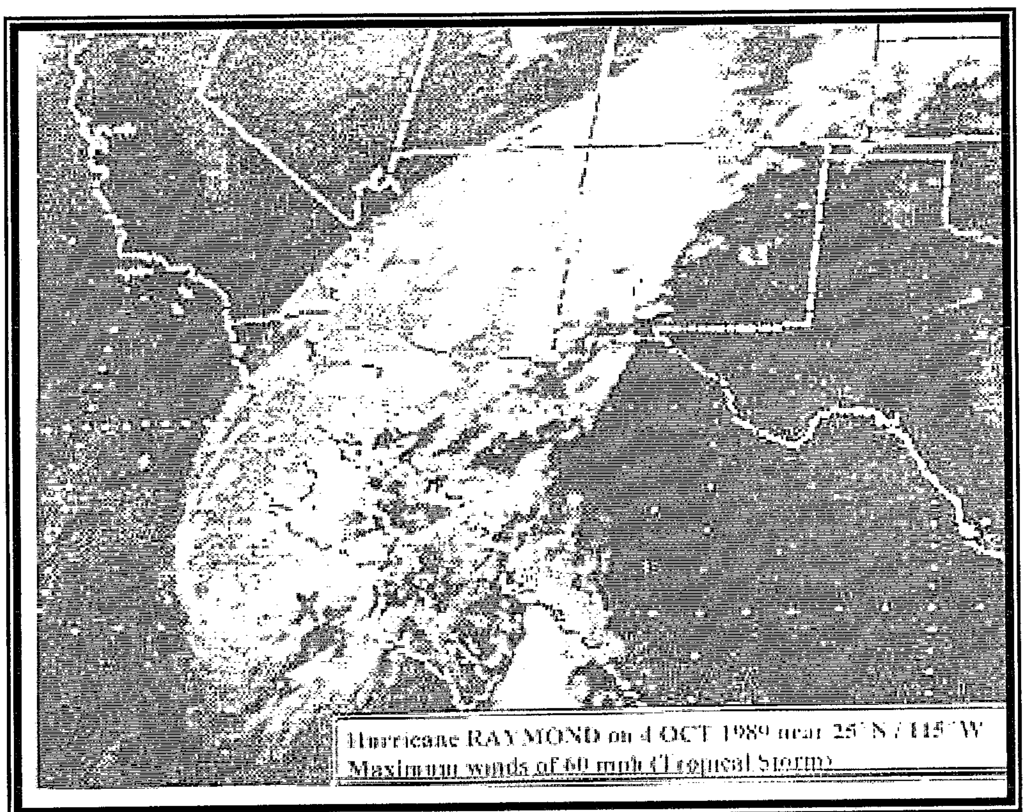


Figure 12 ..... Hurricane Raymond cloudiness to the north being sheared by strong southwesterly flow of 45-65 knots over California, and Arizona.

Table 1989-B provides the best track data for Hurricane Raymond for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1989-B
BEST TRACK FOR HURRICANE RAYMOND

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 25/0000	13.7 N	99.0 W	1007	25	T.D.
/0600	13.9 N	99.6 W	1007	25	T.D.
/1200	14.1 N	100.3 W	1007	25	T.D.
/1800	14.4 N	100.9 W	1007	25	T.D.
SEP. 26/0000	14.5 N	101.2 W	1007	25	T.D.
/0600	14.6 N	101.4 W	1006	30	T.D.
/1200	14.8 N	101.6 W	1005	30	T.D.
/1800	15.2 N	102.0 W	1003	35	T.S.
SEP. 27/0000	15.6 N	102.5 W	1001	35	T.S.
/0600	16.0 N	103.0 W	1001	40	T.S.
/1200	16.1 N	113.4 W	1001	40	T.S.
/1800	15.9 N	103.9 W	1000	45	T.S.
SEP. 28/0000	15.6 N	104.3 W	999	45	T.S.
/0600	15.6 N	104.7 W	997	50	T.S.
/1200	15.7 N	105.3 W	994	55	T.S.
/1800	15.9 N	106.0 W	987	65	HURRICANE
SEP. 29/0000	15.9 N	106.8 W	980	75	HURRICANE
/0600	15.8 N	107.6 W	975	80	HURRICANE
/1200	15.7 N	108.2 W	970	90	HURRICANE
/1800	15.7 N	108.9 W	965	95	HURRICANE
SEP. 30/0000	16.0 N	109.6 W	960	100	HURRICANE
/0600	16.2 N	110.5 W	957	105	HURRICANE
/1200	16.5 N	111.5 W	953	110	HURRICANE
/1800	16.7 N	112.5 W	948	115	HURRICANE
OCT. 01/0000	17.0 N	113.4 W	935	125	HURRICANE
/0600	17.4 N	114.3 W	935	125	HURRICANE
/1200	17.7 N	115.2 W	940	120	HURRICANE

TABLE 1989-B
BEST TRACK FOR HURRICANE RAYMOND

/1800	18.1 N	116.0 W	945	115	HURRICANE
OCT. 02/0000	18.4 N	116.7 W	950	110	HURRICANE
/0600	18.6 N	117.2 W	955	110	HURRICANE
/1200	18.8 N	117.6 W	958	105	HURRICANE
/1800	19.1 N	117.9 W	961	100	HURRICANE
OCT. 03/0000	19.4 N	118.1 W	967	95	HURRICANE
/0600	19.8 N	118.0 W	970	90	HURRICANE
/1200	20.2 N	117.7 W	974	80	HURRICANE
/1800	20.8 N	117.3 W	978	75	HURRICANE
OCT. 04/0000	21.6 N	116.8 W	981	70	HURRICANE
/0600	22.7 N	116.1 W	985	65	HURRICANE
/1200	23.8 N	115.5 W	988	60	T.S.
/1800	25.1 N	114.5 W	992	55	T.S.
OCT. 05/0000	27.0 N	113.3 W	996	45	T.S.
/0600	29.4 N	112.0 W	1000	35	T.S.
/1200	31.8 N	110.2 W	1003	25	T.D.
/1800	33.4 N	108.0 W	1007	20	T.D.

F. Hurricane Boris ..... June 2-8, 1990

The 1990 hurricane season was an above normal year for tropical cyclones over the eastern north Pacific with a total of 20 named tropical cyclones. Avila (1991) noted that this was two short of the record for any given year, but four more than the average. Of these, sixteen (16) made it to hurricane strength.

Figure 13 shows the track of Hurricane Boris.

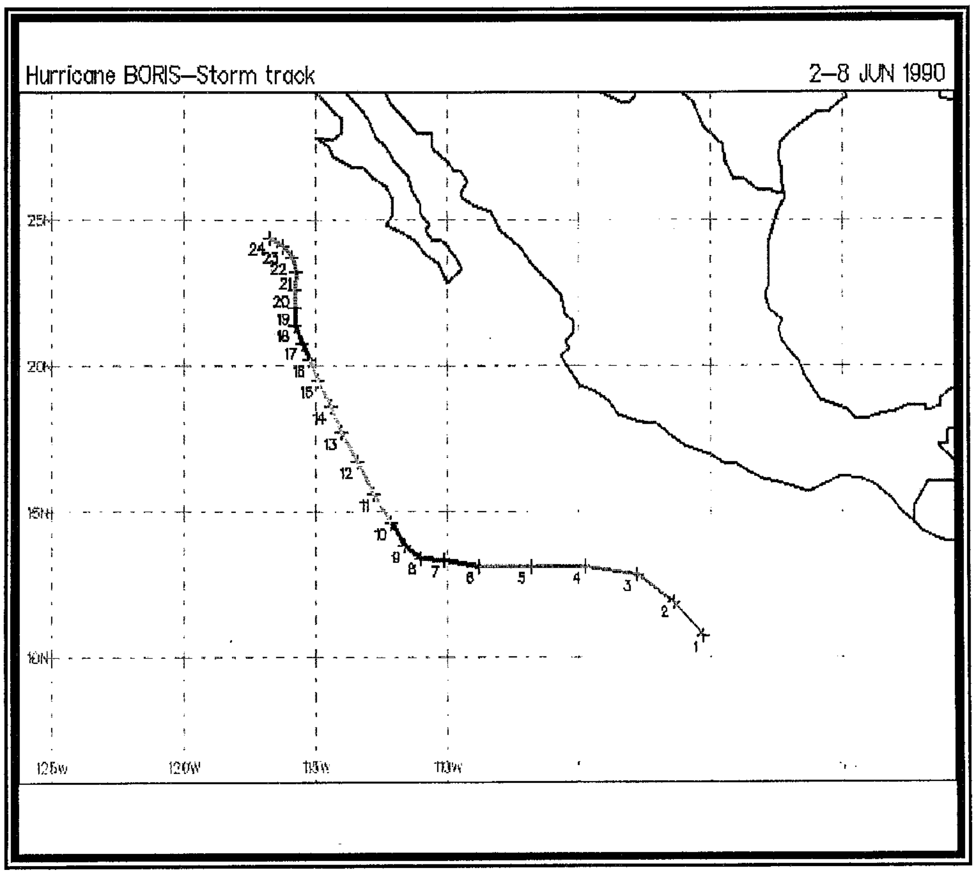


Figure 13 ... **T.D.** (1-5) Jun 02/18Z - 03/18Z; **T.S.** (6-9) Jun 04/00Z - 04/18Z; **HUR** (10-15) Jun 05/00Z - 06/06Z; **T.S.** (16-18) Jun 06/12Z - 07/00Z; **T.D.** (19-24) Jun 07/06Z - 08/12Z.

Synoptic scale conditions for the southwestern U.S. were normal for this time of year. A surface high pressure center was located over western Montana and weak gradients were located elsewhere across California and Arizona.

At 500 mb, zonal flow with 35-50 knot winds existed over the northern half of the country. Much weaker and variable flow of 10 knots or less over the southwestern states was analyzed on June 8th. By June 9th, a more organized flow of southerly winds of 20-30 knots had developed over the southwest. On June 10 a significant southwesterly flow of 30-40 knots was occurring across southern California into Arizona.

As with many tropical systems, this track shows that Hurricane Boris dissipated well south of California. However, the rich tropical moisture was drawn north by the strong southwesterly flow that developed at the mid levels on June 9th.

At San Diego Lindbergh Field, a heavy thunderstorm produced over a third of an inch (.37 inch) of rain in less than half an hour just before 11:00 am on June 9 and contributed to a record rainfall day of .38 inch for the airport. Amounts of 1-2 inches of rain occurred over the San Diego County mountains. Mt. Laguna had 1.41 inches, Escondido 0.98 inch, and Fallbrook 0.87 inch.

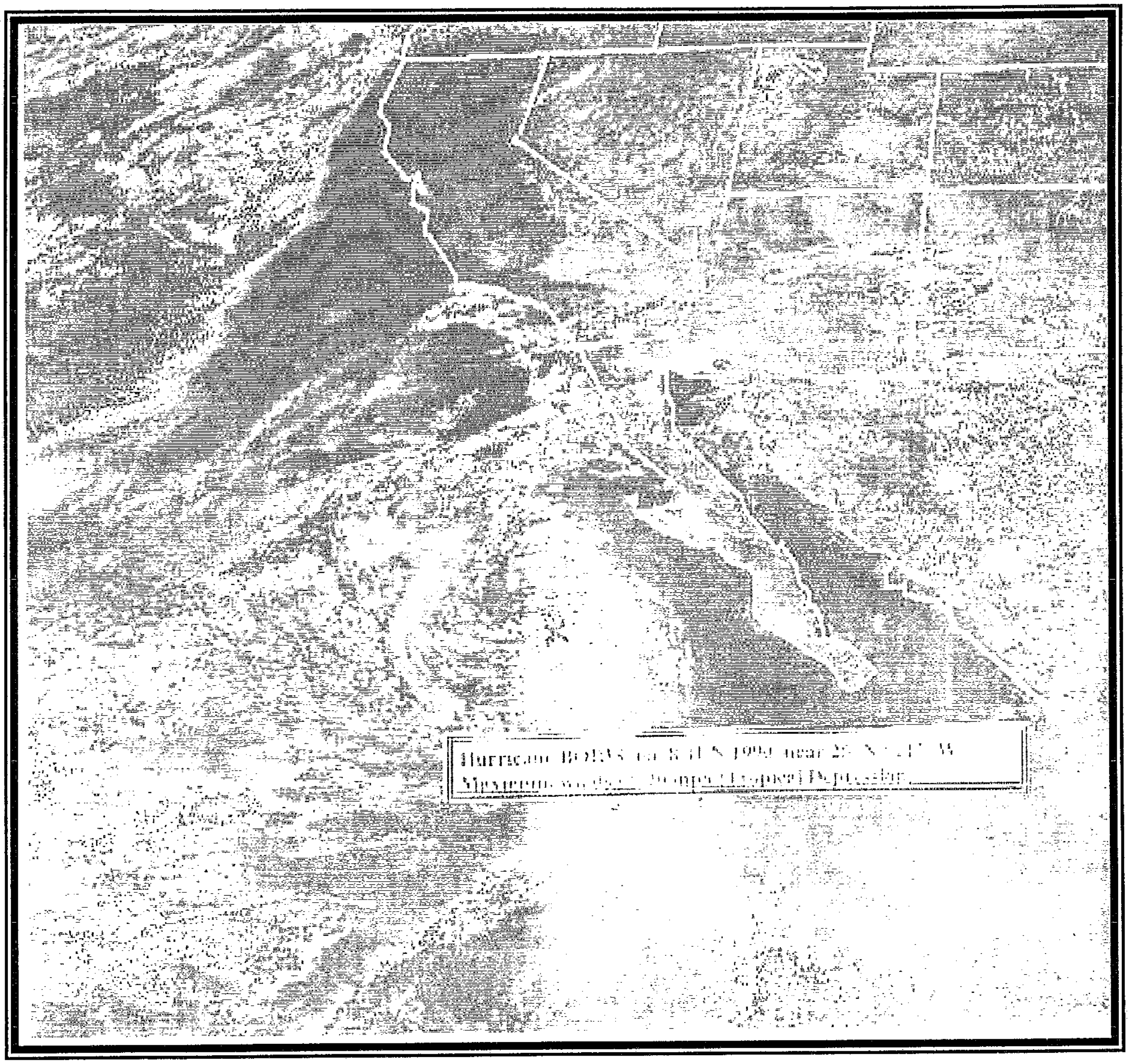


Figure 14 ..... "BORIS" on June 8, 1990 southwest of Baja California.

On June 10 the thunderstorms spawned from Boris continued, with close to half an inch (.49 inch) recorded at the airport and additional larger amounts over the mountains. These thunderstorms also produced lightning throughout San Diego County, knocking out electricity which affected 10,000 residents. Lightning also struck an American Airlines jet, but it landed safely at Los Angeles International Airport.

Moisture from Boris moved into Arizona on June 9 during the late afternoon hours and resulted in scattered thunderstorms rapidly developing in the Phoenix area. Power lines were downed throughout the valley and about 7,200 homes were left without power. A woman in Queen Creek was trapped in a trailer when power lines fell around it.

Table 1990-A provides the best track data for Hurricane Boris for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1990-A
BEST TRACK FOR HURRICANE BORIS

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
JUN. 02/1800	10.7 N	100.3 W	1010	25	T.D.
JUN. 03/0000	11.9 N	101.4 W	1010	25	T.D.
/1200	13.1 N	104.7 W	10080	30	T.D.
04/0000	13.1 N	108.8 W	1005	35	T.S.
/0600	13.3 N	110.1 W	1000	45	T.S.
/1200	13.4 N	111.0 W	995	50	T.S.
/1800	13.8 N	111.6 W	992	60	T.S.
JUN. 05/0000	14.6 N	112.1 W	987	65	HURRICANE
/0600	15.6 N	112.8 W	981	75	HURRICANE
/1200	16,7 N	113.4 W	977	80	HURRICANE
/1800	17.7 N	114.0 W	978	80	HURRICANE
JUN. 06/0000	18.6 N	114.4 W	979	75	HURRICANE
/0600	19.5 N	114.9 W	980	70	HURRICANE
/1200	20.2 N	115.2 W	985	60	T.S.
/1800	20.8 N	115.5 W	995	55	T.S.
JUN. 07/0000	21.4 N	115.8 W	1000	45	T.S.
/0600	22.0 N	115.8 W	1006	30	T.D.
/1200	22.6 N	115.8 W	1007	30	T.D.
/1800	23.2 N	115.7 W	1008	25	T.D.
JUN. 08/0000	23.7 N	115.9 W	1009	25	T.D.
/0600	24.1 N	116.2 W	1010	20	T.D.
/1200	24.4 N	116.7 W	1010	20	T.D.

G. Hurricane Odile ..... September 23 - October 2, 1990

Avila (1991) noted the life cycle and rapid intensification of "Odile" which was tracked beginning on September 23rd when the center was located about 650 miles south southeast of the southern tip of Baja California. Odile reached tropical storm strength on the 24th and became a hurricane on the 25th. By the 28th, the hurricane was north of the 26°C sea-surface-temperature isotherm and weakening as rapidly as it had earlier intensified.

Figure 15 shows the track of Hurricane Odile.

Surface features for the last week of September into the first week of October did not show any deviation from the normal pattern for the southwest U.S. during this time of year. A weak thermal trough was straddling the California -Arizona border. No significant frontal boundaries were found in any sections of California through Arizona.

Aloft however, a 500 mb closed low had become semi-stationary about 300 miles west of San Francisco on September 23-34, and winds over southern California into Arizona were 25-35 knots.

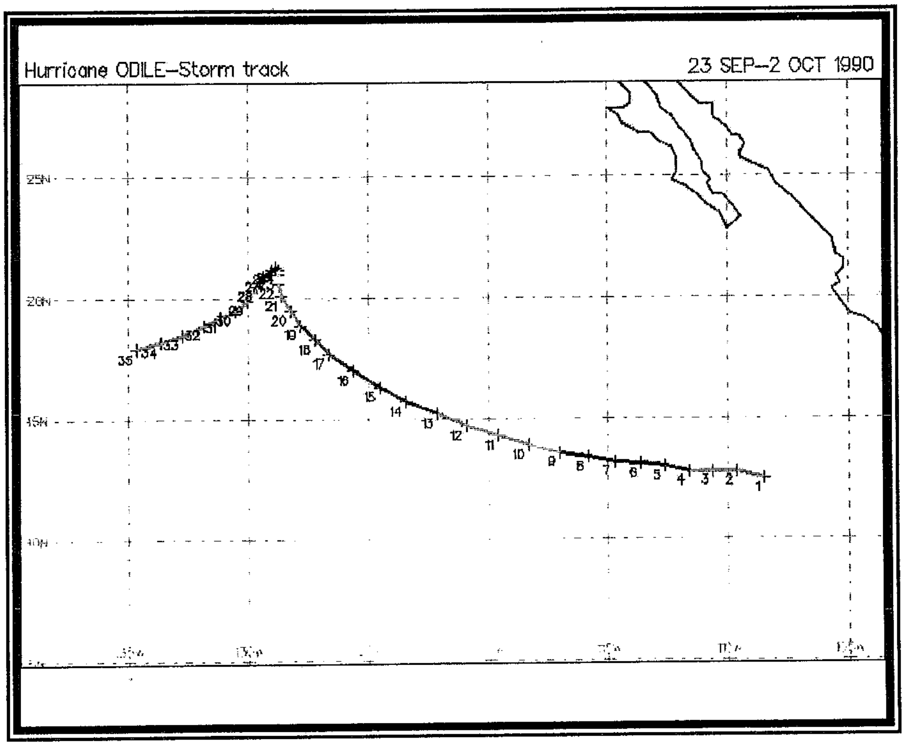


Figure 15 ... **T.D.** (1-3) Sep. 23/12Z - 24/00Z; **T.S.** (4-8) Sep. 24/12Z - 25/06Z; **HUR** (9-23) Sep. 25/12Z - 29/00Z; **T.S.** (24-27) Sep 29/12Z - 30/00Z; **T.D.** (28-35) Sep.30/06Z - Oct. 02/00Z

By the last day of September, the closed upper low had dropped southward and its center was now located approximately 150 miles southwest of San Diego. The following day (October 1) it progressed to a position over north central Baja California due east of Ensenada. It was the southeast penetration of this upper low that was responsible for capturing and steering abundant tropical moisture from Odile across north and central Baja into Arizona. Hurricane Odile was a very good example of why tropical moisture must be monitored, no matter how far away the source may be. In the case of Odile, the track showed it moving to the southwest as it continued to dissipate.

However, the moisture was caught in the mid level flow which transported the rich moisture into Arizona on October 1.

Figure 16 shows the satellite photograph of Tropical Storm Odile on September 29th.

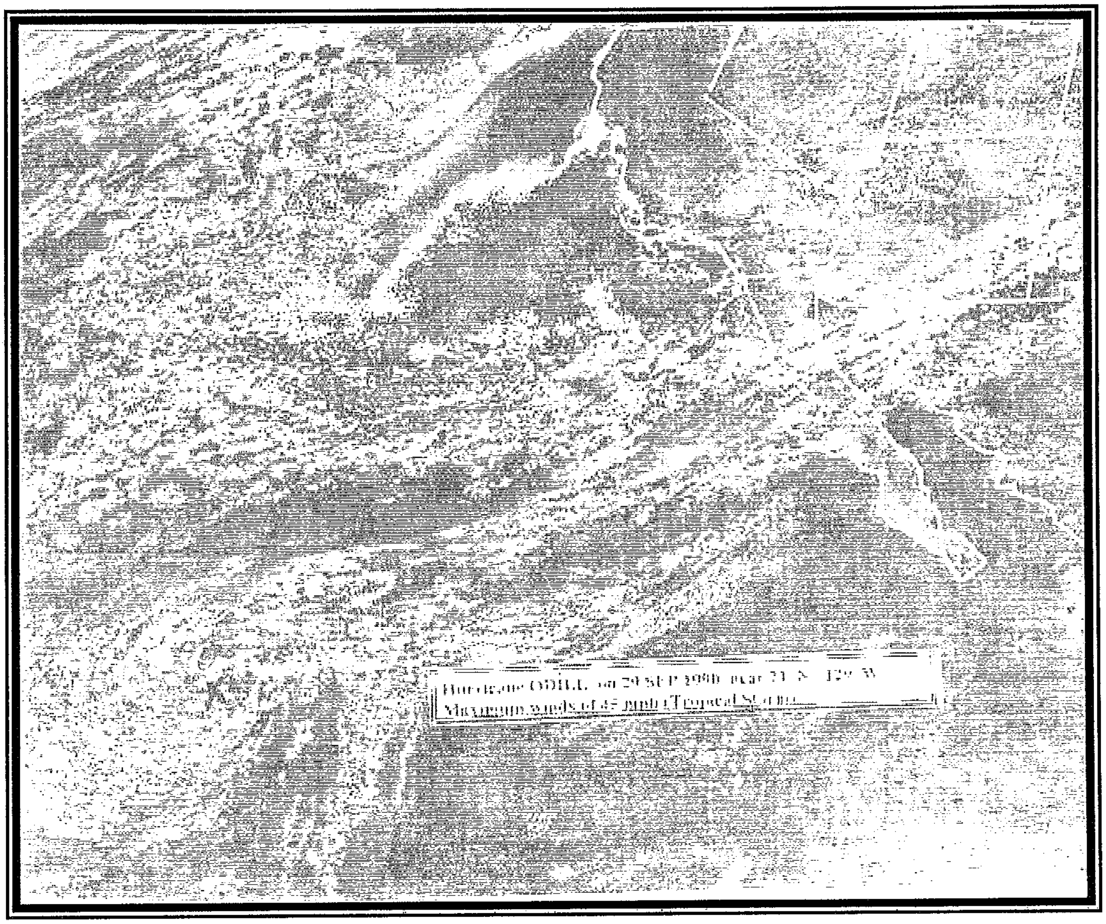


Figure 16 Hurricane Odile dissipating over cooler waters in the Pacific Ocean

Note the plume of moisture extending to the east northeast of the system. This belt of moisture continued for a few days and provided moisture for convective activity over the southwest.

Thunderstorms developed during the afternoon of October 1 over the Arizona deserts and hit the Yuma area with hail and heavy rains. A few homes were flooded. Downtown Yuma had 1.18 inches of rain with quarter-size hail. One area had hail pile up to a depth of 6 inches. The airport received 0.95 inch along with dime-size hail.

Table 1990-B provides the best track data for Hurricane Odile for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1990-B
BEST TRACK FOR HURRICANE ODILE

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 23/1200	12.5 N	108.5 W	1011	25	T.D.
SEP. 24/1200	13.0 N	112.6 W	998	45	T.S.
SEP. 25/1200	13.6 N	117.0 W	980	70	HURRICANE
SEP. 26/1200	15.2 N	122.1 W	935	125	HURRICANE
SEP. 27/0000	16.3 N	124.5 W	935	125	HURRICANE
/0600	17.0 N	125.6 W	935	125	HURRICANE
/1200	17.7 N	126.6 W	935	125	HURRICANE
/1800	18.3 N	127.2 W	946	115	HURRICANE
SEP. 28/0000	18.9 N	127.8 W	960	100	HURRICANE
/0600	19.5 N	128.2 W	963	95	HURRICANE
/1200	20.1 N	128.6 W	970	90	HURRICANE
/1800	20.6 N	128.7 W	980	75	HURRICANE
SEP. 29/0000	21.0 N	128.7 W	988	65	HURRICANE
/0600	21.2 N	128.7 W	994	55	T.S.
/1200	21.3 N	128.8 W	998	50	T.S.
/1800	21.2 N	129.0 W	1002	45	T.S.
SEP. 30/0000	20.9 N	129.3 W	1006	35	T.S.
/0600	20.5 N	129.6 W	1008	30	T.D.
/1200	19.9 N	130.0 W	1010	30	T.D.
/1800	19.5 N	130.5 W	1011	25	T.D.
OCT. 01/0000	19.2 N	131.1 W	1012	25	T.D.
/0600	18.9 N	131.8 W	1012	25	T.D.
/1200	18.5 N	132.7 W	1012	25	T.D.
/1800	18.2 N	133.6 W	1012	20	T.D.
OCT. 02/0000	17.9 N	134.6 W	1012	20	T.D.

H. Tropical Storm Rachel ..... September 27 - October 3, 1990

Tropical Storm Rachel was the only system during 1990 to effectively move north of 25 °N as its track clipped the extreme southern portion of Baja California as it moved northeast into Mexico at 25 °N, finally dissipating near Chihuahua, Mexico before entering Texas to the west of Big Bend.

Figure 17 shows the track of Tropical Storm Rachel.

The synoptic conditions were similar to Odile since Rachel occurred during the same time period.

Therefore, the track of Tropical Storm Rachel was influenced by an upper-level low which tracked just south of southern California. This synoptic scale feature began steering the storm northward when it was about 500 miles south of Cabo San Lucas, Mexico. Rachel recurved with increasing forward speed under the influence of the upper-level low, and moved over the southern tip of Baja California on October 2. The center continued across the Gulf of California and made landfall on the west coast of Mexico midway between Los Mochis and Culiacan.

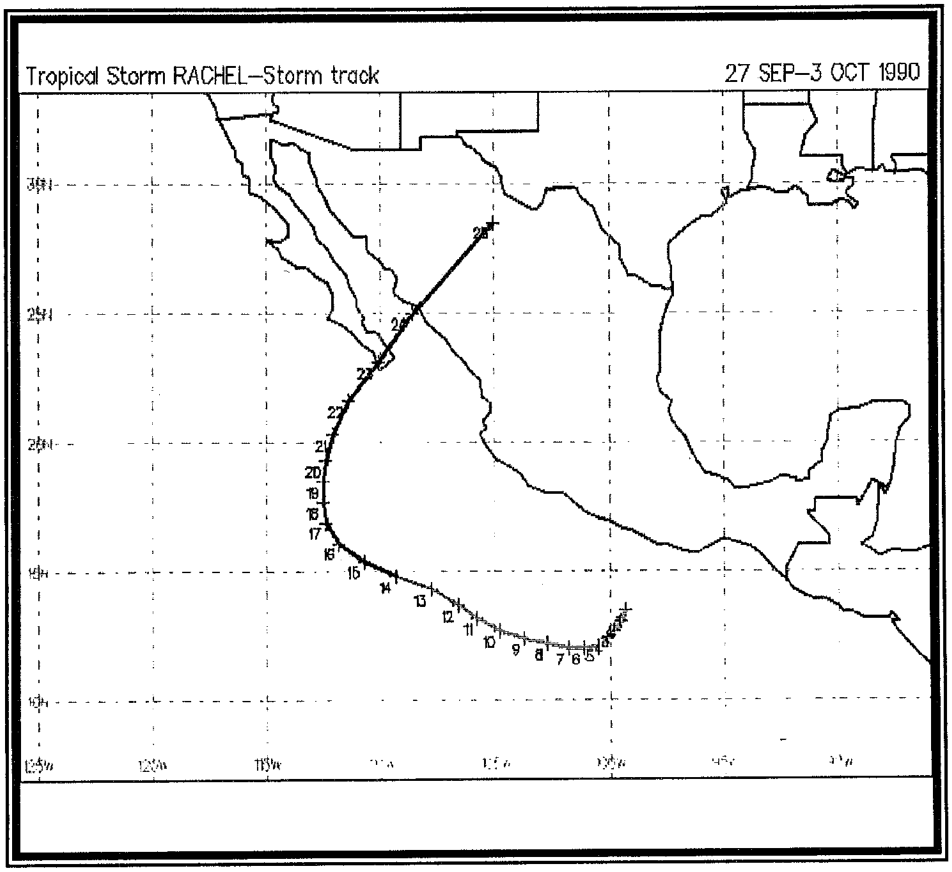


Figure 17 ... **T.D.** (1-13) Sep. 27/00Z - 30/00Z; **T.S.** (14-24) Sep. 30/06Z - Oct. 02/18Z; **T.D.** (25) October 03/00Z.

Avila (1990) and Mayfield stated that the Meteorological Service of Mexico reported a maximum storm related rainfall of 8.5 inches at San Jose Del Cabo near the southern tip of Baja California from Rachel. Although El Paso only reported .83 inch of rain on October 1, remnants of Rachel contributed to heavy rains and flooding over portions of southwest Texas, in the Big Bend area, where some roads were covered with water.

This tropical system did not have any significant impacts on northern Baja, California or Arizona.

Table 1990-C provides the best track data for Tropical Storm Rachael for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1990-C
BEST TRACK FOR TROPICAL STORM RACHEL

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 27/0000	13.5 N	99.3 W	1010	25	T.D.
/1200	12.7 N	99.8 W	1010	25	T.D.
SEP. 28/0000	12.1 N	100.5 W	1009	25	T.D.
/1200	12.0 N	101.8 W	1009	25	T.D.
SEP. 29/0000	12.4 N	103.7 W	1008	30	T.D.
/0600	12.7 N	104.8 W	1008	30	T.D.
/1200	13.2 N	105.8 W	1008	30	T.D.
/1800	13.7 N	106.6 W	1007	30	T.D.
SEP. 30/0000	14.3 N	107.8 W	1006	30	T.D.
/0600	14.8 N	109.3 W	1005	35	T.S.
/1200	15.4 N	110.7 W	1004	40	T.S.
/1800	16.1 N	111.8 W	1002	40	T.S.
OCT. 01/0000	16.9 N	112.4 W	1001	45	T.S.
/0600	17.7 N	112.5 W	999	45	T.S.
/1200	18.5 N	112.5 W	998	50	T.S.
/1800	19.3 N	112.4 W	997	50	T.S.
OCT. 02/0000	20.3 N	112.1 W	995	55	T.S.
/0600	21.6 N	111.4 W	994	55	T.S.
/1200	23.1 N	110.1 W	995	55	T.S.
/1800	25.0 N	108.6 W	997	50	T.S.
OCT. 03/0000	28.5 N	105.0 W	1004	25	T.D.

I. Tropical Storm Hilda ..... August 8 -14, 1991

The 1991 hurricane season was a near normal year for tropical cyclones over the eastern north Pacific. Mayfield et al. (1992) noted that of the fourteen (14) systems that developed, ten (10) made it to hurricane strength. Although never strengthening to hurricane category, the remnants of Hilda moved to approximately 300 miles west of San Diego, California before dissipating.

Figure 18 shows the track of Tropical Storm Hilda.

Surface features showed the typical thermal low across southeast California into western Arizona during August 8-14.

The 500 mb flow showed very weak gradients existing south of 40°N. An upper level low was centered over the northwest portion of the country in the north-central portion of Washington state. Another broad low was developing with a center near 30°N and 130°W, likely a reflection of Hilda at the upper levels.

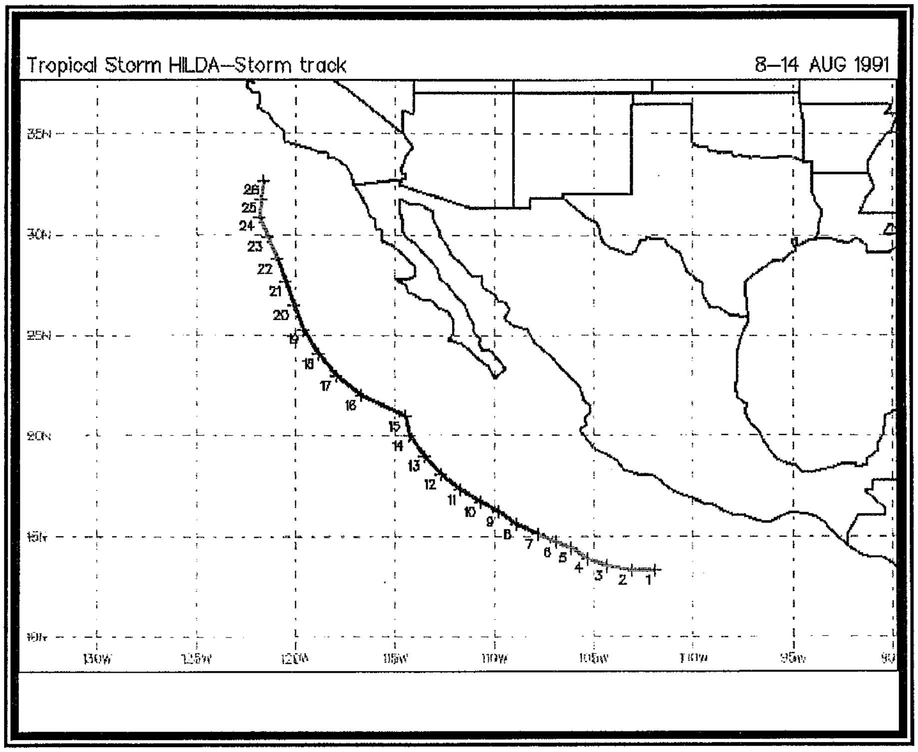


Figure 18 ..... **T.D.** (1-6) Aug. 08/00Z -09/06Z; **T.S.** (7-21) Aug. 09/12Z - 13/00Z; **T.D.** (22-26) Aug.13/06Z - 14/06Z

On August 12th, Hilda was exerting its influence on winds being reported at the 500 mb level over southwest California with San Diego reporting south winds at 25 knots. By August 13th and continuing through the 14th, winds at 18,000 feet increased to 30-35 knots at San Diego, while stronger winds near 50 knots were analyzed just north of Los Angeles. A closed low at this level had positioned itself near 35°N and 125°W.

Hilda's track brought it close enough to supply parts of California with moisture. Although minimal, moisture from the system resulted in rain which produced some thunderstorms over southern California.

Figure 19 shows the satellite photograph with Tropical Storm Hilda when it was centered approximately 370 miles southwest of San Diego, California. Most of the northern part of the moisture band was penetrating Los Angeles County and extending north through Ventura County.

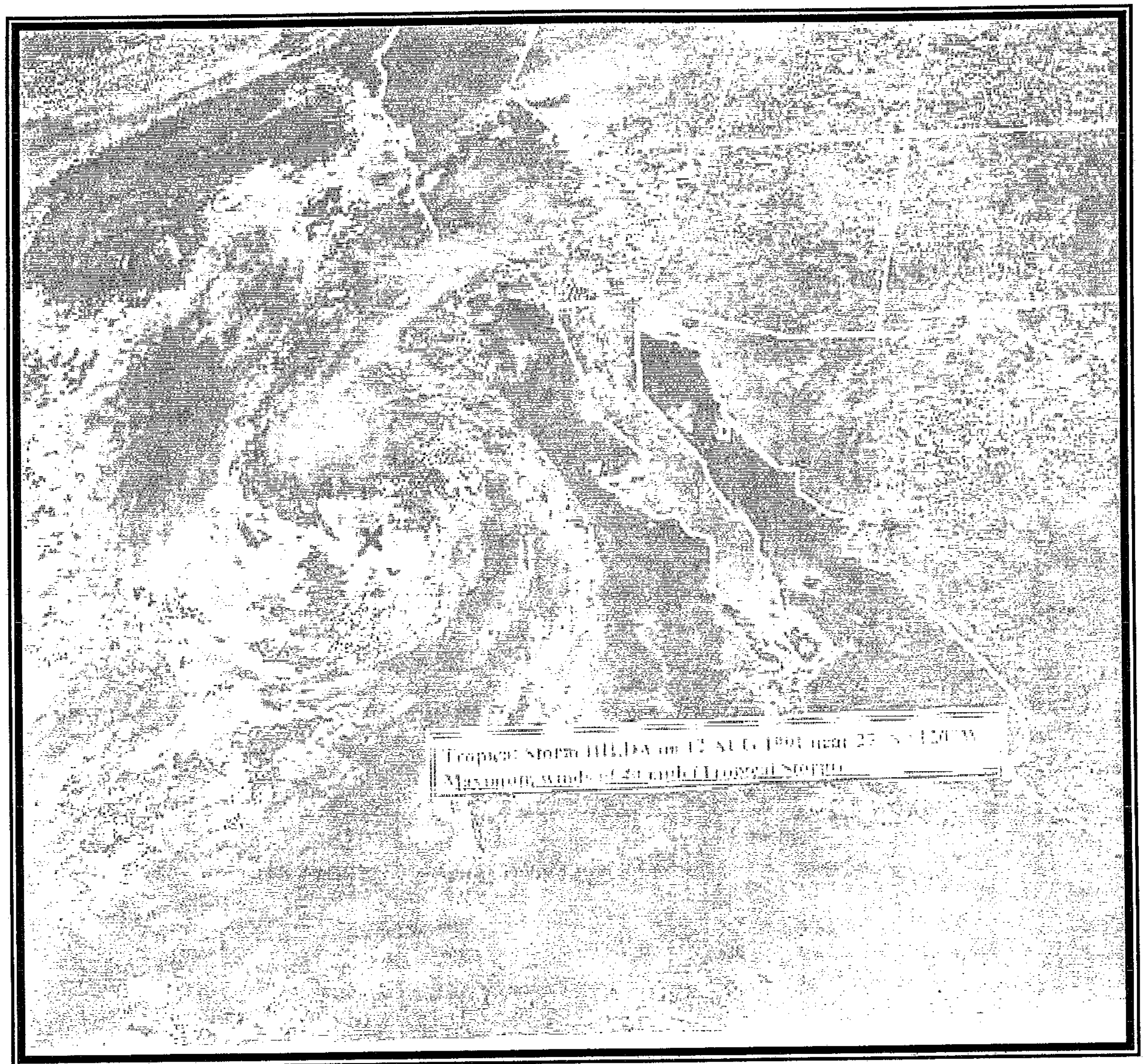


Figure 19 ..... Tropical Storm Hilda located southwest of San Diego, California

Some local flash flooding occurred in the mountains and desert areas of California. Goleta fire station had 0.28 inch of rain, Maria Ygnacio 0.31 inch, San Marcos Pass 0.28 inch, and Refugio had 0.63 inch of rain, all in Santa Barbara and Ventura counties. Only trace amounts were reported over sections of San Diego County throughout the August 12-14 period.

Table 1991-A provides the best track data for Tropical Storm Hilda for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1991-A
BEST TRACK FOR TROPICAL STORM HILDA

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
AUG. 08/0000	13.3 N	101.9 W	1009	25	T.D.
/1200	13.5 N	104.3 W	1009	30	T.D.
AUG. 09/0000	14.4 N	106.1 W	1007	30	T.D.
/0600	14.7 N	106.9 W	1006	30	T.D.
/1200	15.1 N	107.8 W	1005	35	T.S.
/1800	15.6 N	108.9 W	1004	40	T.S.
AUG. 10/0000	16.2 N	109.8 W	1003	45	T.S.
/0600	16.7 N	110.7 W	1000	45	T.S.
/1200	17.3 N	111.7 W	997	50	T.S.
/1800	18.1 N	112.7 W	995	50	T.S.
AUG. 11/0000	19.0 N	113.5 W	993	55	T.S.
/0600	20.0 N	114.3 W	992	55	T.S.
/1200	21.0 N	114.5 W	995	50	T.S.
/1800	22.0 N	116.7 W	1000	45	T.S.
AUG. 12/0000	23.0 N	117.9 W	1003	45	T.S.
/0600	24.1 N	118.8 W	1005	45	T.S.
/1200	25.3 N	119.6 W	1006	45	T.S.
/1800	26.5 N	120.1 W	1008	40	T.S.
AUG. 13/0000	27.7 N	120.5 W	1009	35	T.S.
/0600	28.8 N	120.9 W	1009	30	T.D.
/1200	29.9 N	121.4 W	1010	25	T.D.
/1800	30.9 N	121.8 W	1010	25	T.D.
AUG. 14/0000	31.8 N	121.7 W	1010	25	T.D.
/0600	32.7 N	121.6 W	1010	25	T.D.

J. Hurricane Lester ..... August 20-24, 1992

The 1992 hurricane season was an extremely busy season for tropical cyclones over the eastern north Pacific. Lawrence et al. (1994) documented a total of 27 tropical systems that formed, which is about a dozen above normal. Of these, fourteen (14) strengthened to become hurricanes.

Figure 20 shows the track of Hurricane Lester.

Surface features over the western U.S. several days before Hurricane Lester made landfall in Baja California showed a weak frontal boundary moving south across California. This cold front moved from the northern part of the state on August 20th into extreme southeast California by August 23rd.

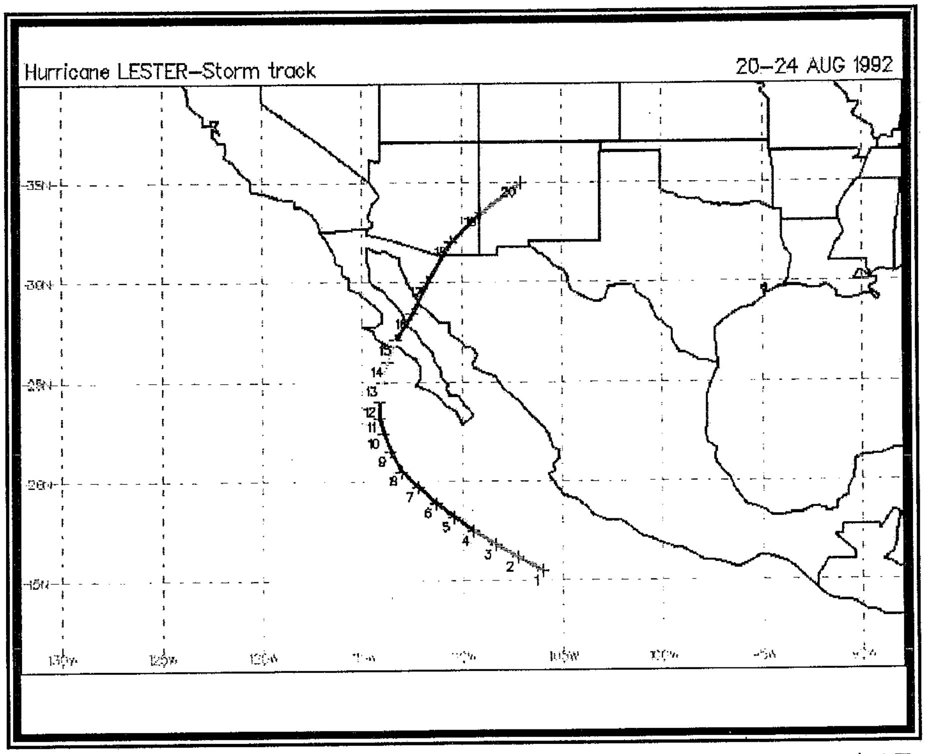


Figure 20 ... **T.D.** (1-3) Aug. 20/00Z - 12Z; **T.S.** (4-11) Aug. 20/18Z - 22/12Z; **HUR** (12-14) Aug. 22/18Z - 23/06Z; **T.S.** (15-18) Aug. 23/12Z - 24/06Z; **T.D.** (19-20) Aug. 24/12Z - 24/18Z.

Hurricane Lester entered Baja California on August 23rd near Punta Abreojos , continuing northeast across the Gulf of California and entering Mexico just north of Guaymas.

On August 24th, Lester crossed into the United States near Nogales, due south of Tucson, Arizona.

When Lester crossed Baja California, a 500 mb longwave trough was in place over the western United States extending as far south as latitude 28°N. Rich tropical moisture from the system was therefore able to move north mainly on August 23-24 into an already unstable airmass in place over southern California east through Arizona. The addition of this tropical moisture resulted in development of thunderstorms.

The satellite photograph on Figure 21 shows Lester as it moved across the of Gulf of California still maintaining the characteristics of a tropical storm. Several authors (Lawrence and Rapport) noted that this was the first time since Katrina in 1967 that an eastern North Pacific tropical cyclone retained at least tropical storm intensity upon reaching the United States. Both satellite imagery and surface observations suggest that Lester probably was a minimal tropical storm as far inland as Tucson, Arizona, and dissipated in central New Mexico.

Lawrence (1994) indicated that Lester left more than 5000 people homeless in Mexico. Several small communities were destroyed west of the city of Hermosillo and on the highway that leads from there to San Diego.

In California, a flash flood watch was issued for portions of Imperial County as thunderstorms producing heavy rainfall were occurring on Highway 78 near Palo Verde. Heavy rainfall also occurred over southern Arizona as Lester moved across north Mexico, with localized reports of 2-3 inches reported between Tucson and Nogales.

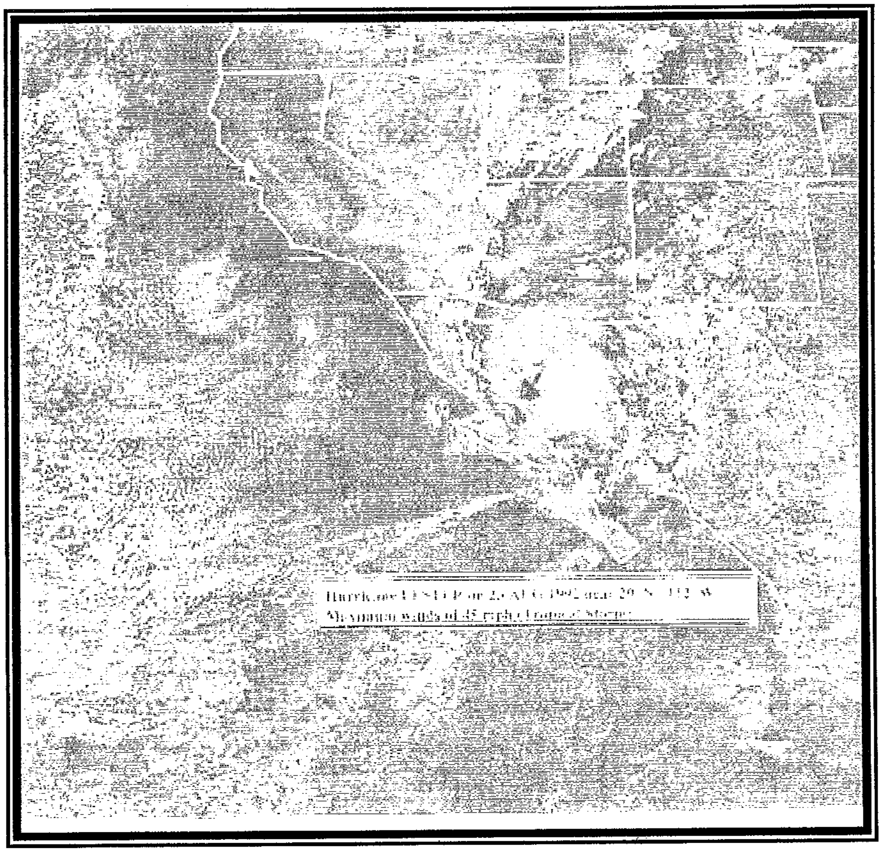


Figure 21 Satellite photograph of "Lester" on August 22, 1992.

Storm reports indicated flash flooding occurred on August 23rd in the Vidal Junction area near Blythe, California. The California Highway Patrol reported Highways 95 and 62 were closed due to flooding. Additionally, heavy thunderstorms in the Death Valley area caused some local flash flooding. During the afternoon, park officials at Death Valley Ranger Station, reported flash flooding in the Immigrant Canyon and Wildrose area, south of Route 190.

In Arizona, widespread heavy rains left many streets and highways under water on August 22. About one inch of rain fell in New River and 1.25 inches at Apache Junction within a 30 minute period, while Wickenburg received almost one inch in only 10 minutes. Numerous rescues were performed by Rural Metro Fire Department in Scottsdale.

The following day, heavy rains generated by Lester's rich tropical moisture caused rare August water releases from the Granite Reef Diversion Dam into the normally dry Salt River bed. Releases continued and forced closure of many un-bridged crossings along the Salt River. Peak releases of 17,500 cfs occurred at Granite Reef Dam. At least one death was indirectly related to the heavy flows in the Salt River as a 19 year old man drowned on August 24 as he attempted to cross the raging waters west of Phoenix, Arizona. Flash flooding also occurred in Parker in La Paz County where up to 5.50 inches of rain fell during the two day period. Residents noted that this was one of the worst natural disasters they could recall. Roads and streets were closed and a mobile home park had more than 2 feet of water standing several hours after the storms ended.

Table 1992-A provides the best track data for Hurricane Lester for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1992-A
BEST TRACK FOR HURRICANE LESTER

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
AUG. 20/0000	15.5 N	106.0 W	1011	25	T.D.
/0600	16.2 N	107.2 W	1009	30	T.D.
/1200	16.8 N	108.3 W	1008	30	T.D.
/1800	17.5 N	109.4 W	1005	35	T.S.
AUG. 21/0000	18.2 N	110.4 W	1004	35	T.S.
/0600	18.9 N	111.3 W	1003	40	T.S.
/1200	19.7 N	112.2 W	1002	40	T.S.
/1800	20.5 N	113.0 W	1000	45	T.S.
AUG. 22/0000	21.5 N	113.6 W	998	50	T.S.
/0600	22.4 N	113.9W	994	55	T.S.
/1200	23.2 N	114.1 W	990	60	T.S.
/1800	24.0 N	114.1 W	985	70	HURRICANE
AUG. 23/0000	25.0 N	114.0 W	985	70	HURRICANE
/0600	26.0 N	113.7 W	987	65	HURRICANE
/1200	27.1 N	113.3 W	994	55	T.S.
/1800	28.4 N	112.5 W	996	45	T.S.
AUG. 24/0000	30.0 N	111.7 W	998	40	T.S.
/0600	32.0 N	110.5 W	999	35	T.S.
/1200	33.5 N	109.0 W	1004	25	T.D.
/1800	35.0 N	107.0 W	1006	20	T.D.

K. Hurricane Hilary ..... August 17-27, 1993

The 1993 hurricane season was a normal year for tropical cyclones over the eastern north Pacific with a total of 14 systems developing. Of these ten (10) made it to hurricane strength. Two moved north and northeast across Mexico. Lidia curved eastward and moved into Texas in mid September and will not be discussed here. Hurricane Hilary, on the other hand, provided some moisture for the southwestern United States as it dissipated just east of Puerto Peñasco in northern Mexico. Its influence resulted in flash flooding over portions of California and Arizona.

Figure 22 shows the track of Hurricane Hilary.

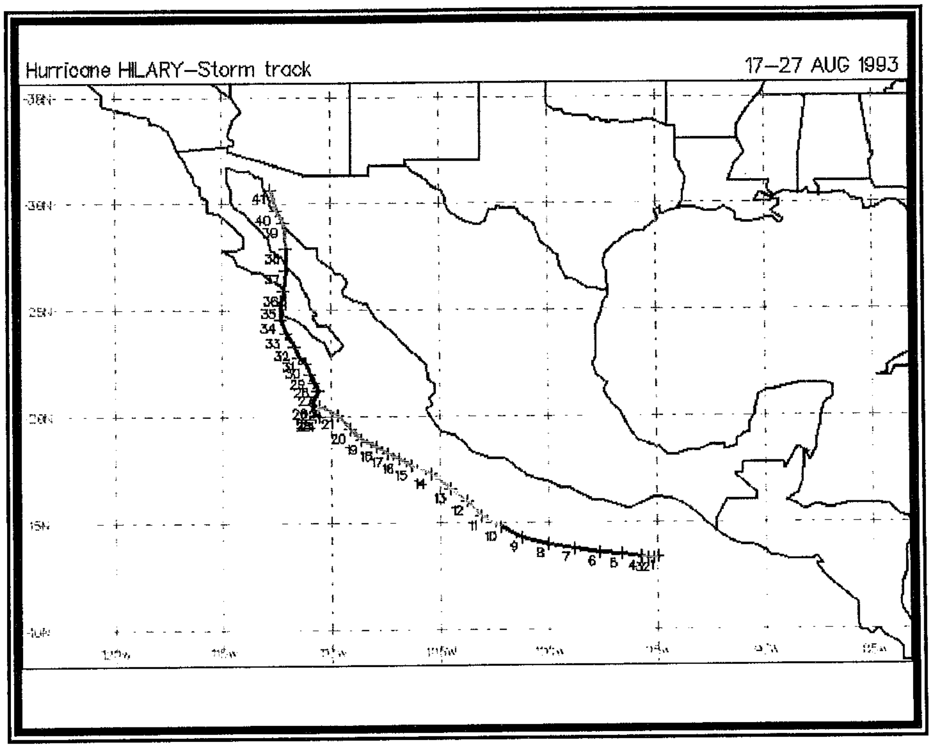


Figure 22 ... **T.D.** (1-3) Aug. 17/06Z - 17/18Z; **T.S.** (4-9) Aug. 18/00Z -19/06Z; **HUR** (10-23) Aug. 19/12Z - 22/18Z; **T.S.** (24-37) Aug. 23/00Z - 26/06Z; **T.D.** (38-41) Aug. 26/12Z - 27/06Z.

As Hurricane Hilary moved north across Baja California, surface dew points increased into the upper 60s to mid 70s over southern California into southeast Arizona. Surface gradients remained weak and there were no organized systems affecting the southwest.

At the 500 mb level, a longwave trough was moving east across the northern portion of the country. The southern extent of this trough reached into the northern California and Nevada area on August 25th and continued east into the central portions of the country by August 27th. Low and mid level flow over the southwest remained southerly at 15-30 knots throughout the same period.

Avila et al. (1995) noted that Hurricane Hilary nearly stalled while executing a small cyclonic loop about 170 miles south of Baja California. The looping was likely an influence from synoptic scale interactions with Tropical Storm Irwin which was located several hundred miles to the southeast of Hilary. However, neither this effect nor the cooler waters were able to destroy the circulation, and within a 24 hour period, the atmospheric environment became more favorable for some strengthening and Hilary reintensified as a 200-mb high developed over the system triggering deep convection near the circulation center.

Figure 23 shows the satellite photograph of Hurricane Hilary as it made landfall on August 25th over southern Baja California. It moved north and came ashore on mainland Mexico as a tropical depression west of Hermosillo. Rainfall amounts across Mexico were significant: 11.35 inches at Derivadora Jala, Comima; 3.98 inches at La Villita, Michoacan, and 4.33 inches at Huerta Vieja, Baja California. Additionally, Manzanillo received 5.37 inches, and Cabo San Lucas 1.46 inches.

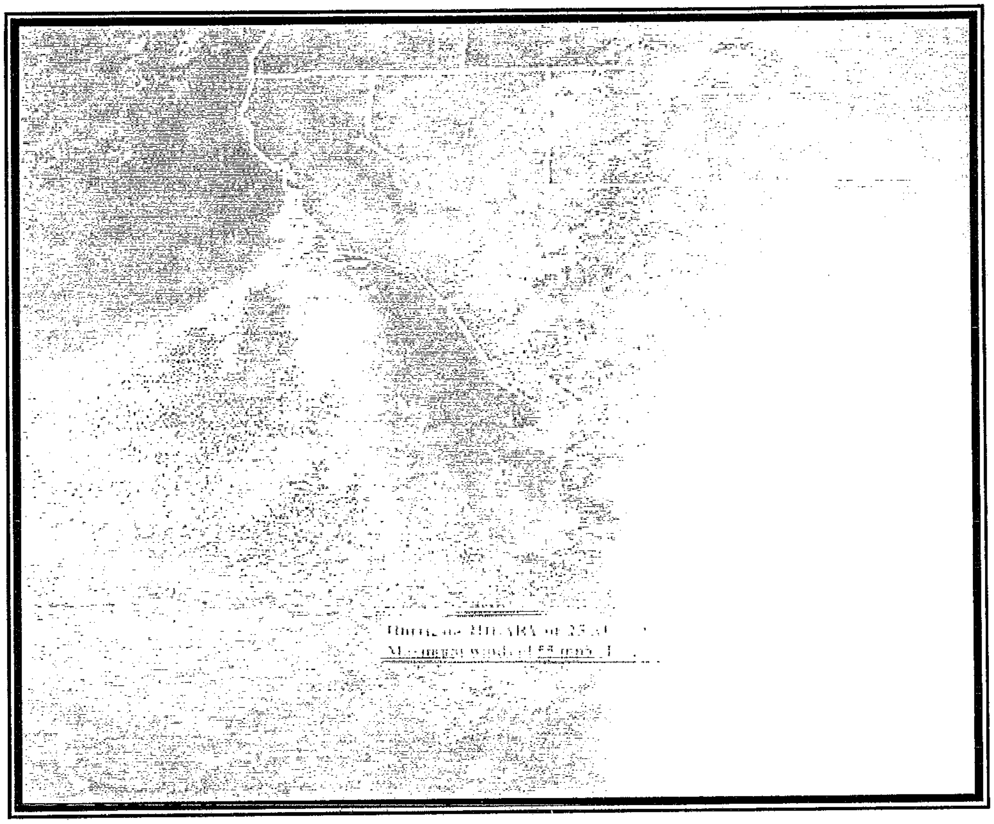


Figure 23 Hurricane Hilary on August 25, 1993

In Arizona, the tropical moisture introduced into a very hot environment, helped to trigger some strong thunderstorms which resulted in flash flooding. Remnant moisture resided over Arizona for a few days and several more flash flood events occurred through August 28th. Largest rainfall totals with the initial penetration of Hilary into Arizona were: Avra Valley Airport with 2.48 inches, Organ Pipe Cactus National Monument with 2.35 inches, and Kitt Peak Observatory with 2.25 inches.

The moisture from Hilary crossed over into California and on August 25th, heavy rain was reported from thunderstorms, in the San Bernardino and San Jacinto mountains and in the Morongo Valley and Desert Hot Springs areas. Local flash flooding damaged 15 to 20 homes and flooded roads in the Morongo Valley area and flooding hit the Yucca Valley area, mainly in dry washes. Flash flooding also hit the Desert Hot Springs area, with 3.00 to 4.00 inches of rain in two hours, flooding many roads. August 26th was less active but a spotter reported that 3 to 4 feet of water was on the roads in Yucaipa after experiencing about an hour of heavy rains from thunderstorms.

Table 1993-A provides the best track data for Hurricane Hilary for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1993-A
BEST TRACK FOR HURRICANE HILARY

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
AUG. 17/0600	13.4 N	94.9 W	1009	25	T.D.
/1200	13.3 N	95.1 W	1008	30	T.D.
/1800	13.3 N	95.4 W	1007	30	T.D.
AUG. 18/0000	13.4 N	95.7 W	1006	35	T.S.
/0600	13.5 N	96.6 W	1003	40	T.S.
/1200	13.6 N	97.6 W	1000	45	T.S.
/1800	13.8 N	98.8 W	996	50	T.S.
AUG. 19/0000	14.0 N	100.0 W	993	55	T.S.
/0600	14.3 N	101.2 W	990	60	T.S.
/1200	14.8 N	102.2 W	987	65	HURRICANE
/1800	15.3 N	103.1 W	984	70	HURRICANE
AUG. 20/0000	16.0 N	103.7 W	981	75	HURRICANE
/0600	16.6 N	104.5 W	978	75	HURRICANE
/1200	17.3 N	105.4 W	975	80	HURRICANE
/1800	17.7 N	106.3 W	970	90	HURRICANE
AUG. 21/0000	18.0 N	106.9 W	965	90	HURRICANE
/0600	18.3 N	107.4 W	960	100	HURRICANE
/1200	18.6 N	107.9 W	957	105	HURRICANE
/1800	18.9 N	108.6 W	957	105	HURRICANE
AUG. 22/0000	19.4 N	109.1 W	960	100	HURRICANE
/0600	20.1 N	109.7 W	963	95	HURRICANE

TABLE 1993-A
BEST TRACK FOR HURRICANE HILARY

/1200	20.5 N	110.5 W	973	85	HURRICANE
/1800	20.0 N	110.7 W	983	70	HURRICANE
AUG. 23/0000	20.0 N	110.5 W	990	60	T.S.
/0600	20.1 N	110.7 W	995	55	T.S.
/1200	20.6 N	110.9 W	998	50	T.S.
/1800	21.2 N	110.6 W	999	45	T.S.
AUG. 24/0000	21.6 N	110.8 W	1000	40	T.S.
/0600	22.0 N	111.0 W	1001	35	T.S.
/1200	22.5 N	111.2 W	1000	35	T.S.
/1800	22.8 N	111.5 W	998	40	T.S.
AUG. 25/0000	23.3 N	111.7 W	996	45	T.S.
/0600	23.9 N	112.1 W	994	50	T.S.
/1200	24.6 N	112.3 W	993	50	T.S.
/1800	25.3 N	112.3 W	991	55	T.S.
AUG. 26/0000	25.9 N	112.2 W	995	50	T.S.
/0600	26.9 N	112.1 W	1005	35	T.S.
/1200	27.9 N	112.1 W	1007	30	T.D.
/1800	29.1 N	112.2 W	1008	30	T.D.
AUG. 27/0000	29.7 N	112.5 W	1009	25	T.D.
/0600	30.7 N	112.8 W	1011	20	T.D.

In talking about the 1994 season, Pasch et al (1995) indicated that the 1994 eastern North Pacific tropical cyclone season was near average with 17 tropical storms developing, 9 strengthening to hurricane category. However most storms, with the exception of one, tracked away from land and had no impact on the southwestern U.S. Hurricane Rosa, although briefly described here, is not included in Table 1 since its impacts were quite removed from California, Arizona, and northern Mexico.

Figure 24 shows the track of Hurricane Rosa which formed on October 8 about 450 miles south-southwest of Baja California. After increasing to hurricane strength on October 12th, it moved northeast making landfall about 70 miles south-southeast of Mazatlan.

Reports received from the Mexican Weather Service indicated that five people were killed in association with Hurricane Rosa. More than 100,000 people suffered partial losses of homes in Nayarit. A large number of telephone and power lines as well as homes were damaged in the state of Sinaloa. Heavy floods and mudslides occurred mainly in the mountains. Rosa moved northeast and weakened as it crossed the Mexican mountains, dissipating on October 15th near the Texas border.

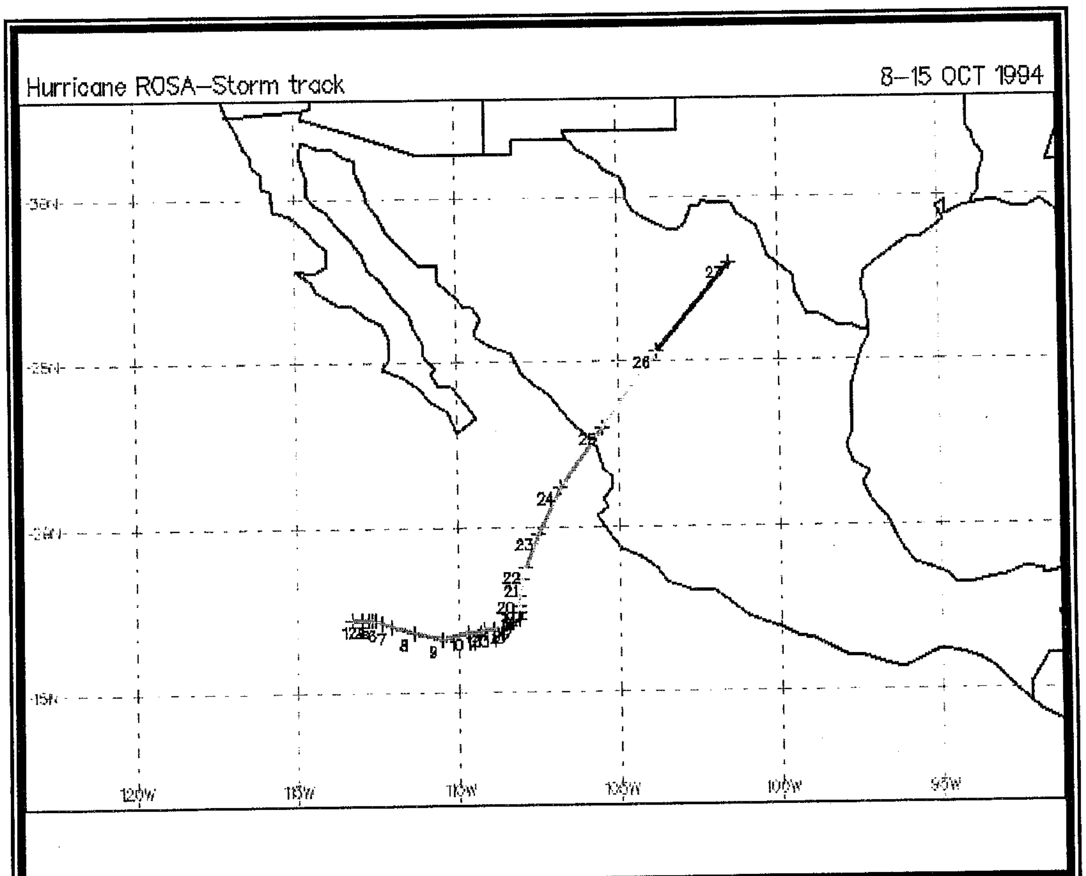


Figure 24 ..... Hurricane Rosa affected interior Mexico and moved into Texas.

L. Hurricane Ismael ..... September 12-15, 1995

There were a total of ten tropical cyclones in the eastern North Pacific during the 1995 hurricane season. Of these, only seven strengthened to hurricane category and the only system which moved north of latitude 25°N was Hurricane Ismael.

Hurricane Ismael developed at longitude 109°W and move almost due north during its life cycle, responding to a mid- to upper- level low over Baja California. It dissipated over northern Mexico just south of the Arizona and New Mexico late on September 15.

Figure 25 shows the track of Hurricane Ismael.

Surface features showed a prominent thermal low over the California and Arizona border. High temperatures during the period of September 13-15 were mainly in the low 100s in this area. Dew point temperatures increased from the upper 40s to the low to mid 60s as Ismael approached the U.S. border.

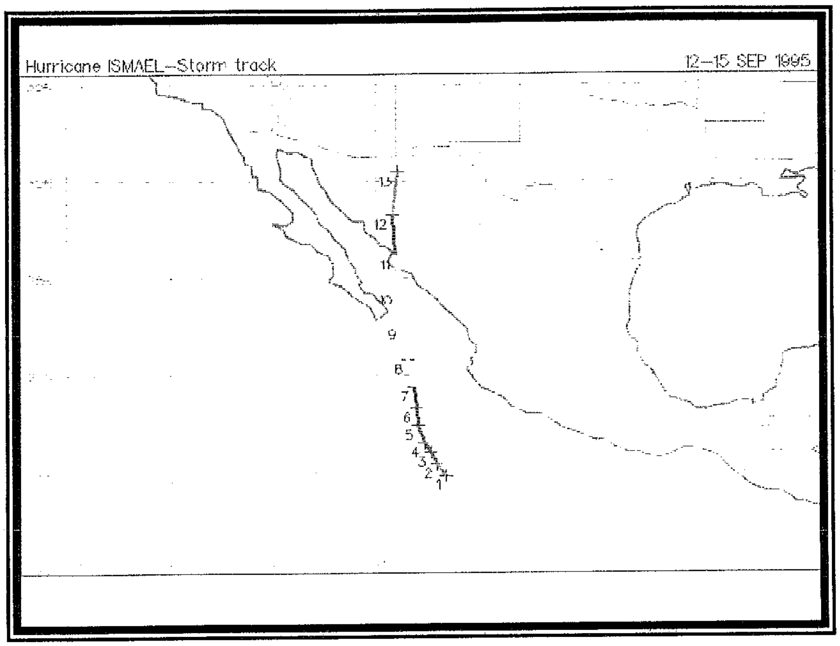


Figure 25 ... **T.D.** (1) Sep. 12/18Z; **T.S.** (2-6) Sep. 13/00Z - 14/00Z; **HUR** (7-10) Sep. 14/06Z - 15/00Z; **T.S.** (11-12) Sep. 15/06Z - 15/12Z; **T.D.** (13) Sep. 15/18Z.

At the 500 mb level, a well defined ridge was in place over the southwest U.S. extending into the state of Washington. The long wave trough was situated over the Great Lakes. By September 15th, a trough had developed to the west of California.

Therefore, as Ismael moved into Mexico, the forward motion of the hurricane increased to just under 20 knots as it was steered by the mid and upper level trough to the west, and a deep-layer-mean ridge to the east.

Ismael carried considerable moisture into Mexico which resulted in rainfall over many portions of the southwestern United States. Arizona reported an increase in thunderstorm activity on September 18th, but most of the heavier rainfall amounts of one to two inches were observed over southeast New Mexico into west Texas.

With Hurricane Ismael, major destruction was limited to areas in Mexico. Newspapers reported 105 fatalities. Most of the victims were fishermen who were caught in the Gulf of California by strong winds and high seas.

The satellite photograph on Figure 26 shows the extensive area of moisture that was transported northeast across northern Mexico into west Texas ahead of Hurricane Ismael. Most of the precipitation occurred over New Mexico and Texas.

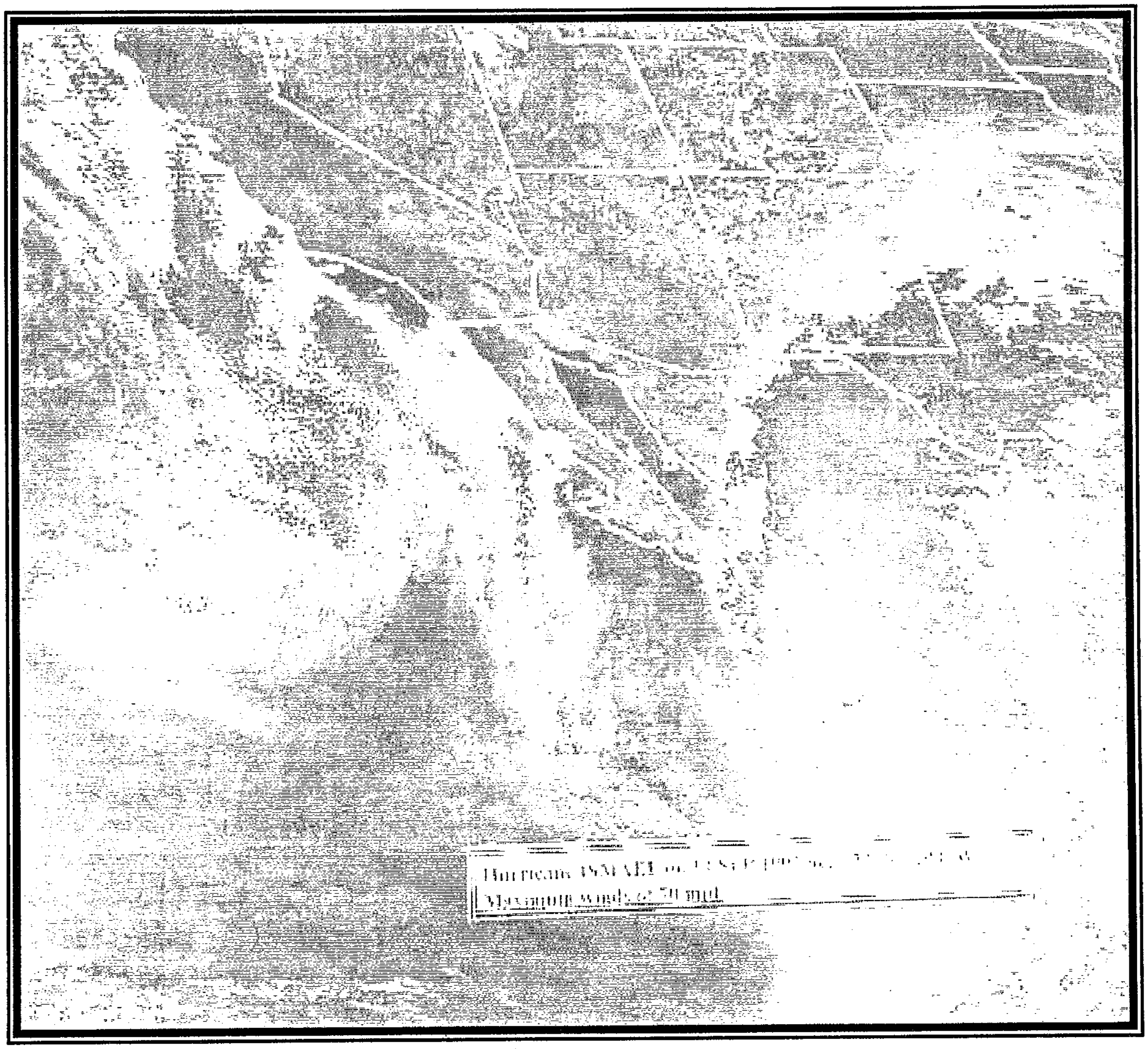


Figure 26 Hurricane Ismael entering southern tip of Gulf of California.

Avila and Rappaport (1996) indicated that some of the unofficial newspaper fatality reports of close to 105 deaths, if accurate, would make Ismael the fifth deadliest eastern Pacific hurricane this century. A report from the government of Mexico placed the number of deaths at 57.

Rapport et al (1998) noted that the Associated Press reported thousands homeless as a result of the hurricane and about 5000 "rickety houses" destroyed. Some of the worst damage was in the village of Topolobampo, Mexico, which is located a few miles to the south of Los Mochis, as Hurricane Ismael crossed over the village during the late night hours of September 15.

Ismael weakened rapidly when it encountered frictional resistance as it crossed the Sierra Madre range of northern Mexico, finally dissipating on September 16. Satellite continued to track its moisture for several days as it moved east through the mid-Atlantic states.

In New Mexico, remnants of Ismael dumped as much as 10 inches of rain over portions of southern and central parts of Lea County. The cities of Hobbs and Eunice were closed with parts of some roads washing out. In Hobbs some streets were flooded waist deep and a soccer field had standing water eight feet deep. The Texas/New Mexico Railroad line between Jal and Hobbs was washed out in three spots suspending travel on the tracks for over a week.

Table 1995-A provides the best track data for Hurricane Ismael for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1995-A
BEST TRACK FOR HURRICANE ISMAEL

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 12/1800	14.8 N	106.7 W	1009	30	T.D.
SEP. 13/0000	15.4 N	107.1 W	1005	35	T.S.
/0600	16.0 N	107.4 W	1002	40	T.S.
/1200	16.5 N	107.7 W	1000	45	T.S.
/1800	17.4 N	108.0 W	995	50	T.S.
SEP. 14/0000	18.3 N	108.1 W	990	60	T.S.
/0600	19.4 N	108.2 W	985	65	HURRICANE
/1200	20.8 N	108.5 W	983	70	HURRICANE
/1800	22.6 N	108.8 W	984	70	HURRICANE
SEP. 15/0000	24.4 N	109.0 W	986	70	HURRICANE
/0600	26.2 N	109.1 W	990	60	T.S.
/1200	28.3 N	109.2 W	1000	45	T.S.
/1800	30.5 N	109.0 W	1008	30	T.D.

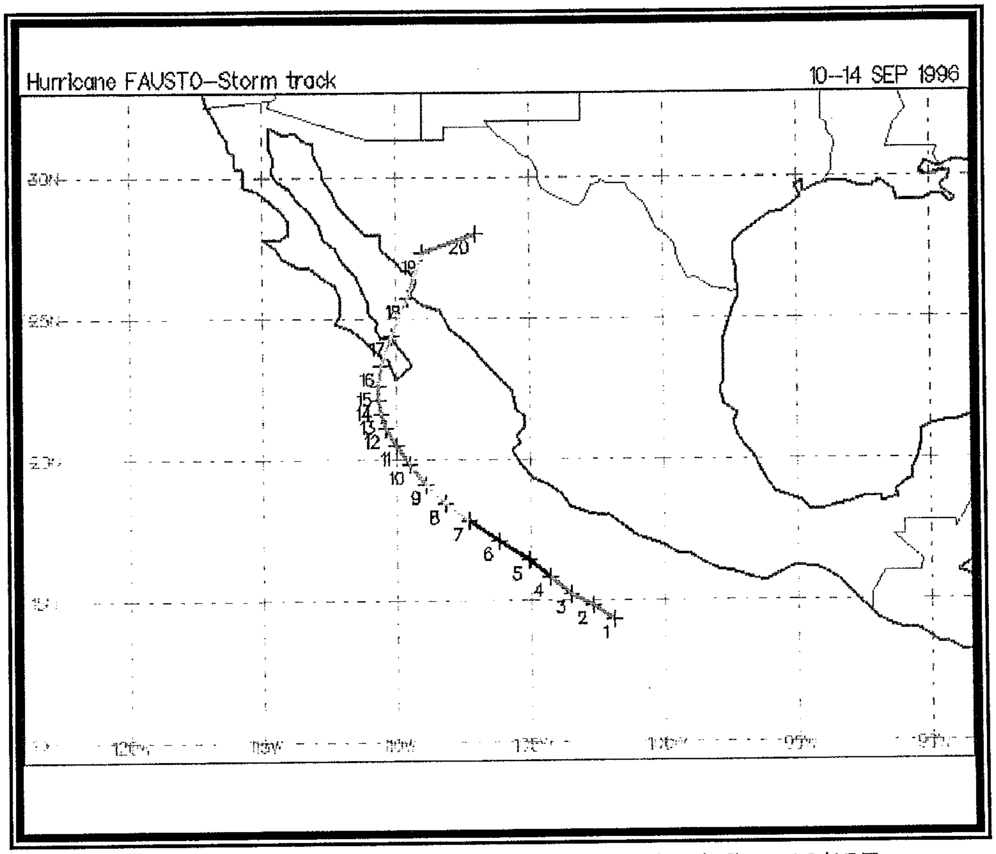
M. Hurricane Fausto ..... September 10-14, 1996

There were a total of nine tropical cyclones in the eastern North Pacific during the 1996 Hurricane season. Of these, five increased to hurricane strength, and the only system which moved north of latitude 25°N was Hurricane Fausto.

Figure 27 shows the track of Hurricane Fausto.

Surface features ahead of Fausto showed an elongated thermal trough extending from the California-Arizona border north across central Nevada. Weak surface gradients existed over northern Mexico.

At the 500 mb level, a long wave trough was entering the west coast on September 13th and progressed east into Arizona by September 14th.



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This synoptic situation was an unfavorable scenario which would not allow Fausto to penetrate northward. The mid-upper level winds over southern California were northwesterly 40-50 knots across Los Angeles into San Diego shifting to southwesterly 35-45 knots across southern Arizona and New Mexico, which forced Fausto to track east once it entered Mexico.

Hurricane Fausto crossed the extreme southern tip of Baja California just to the north of Cabo San Lucas on September 13th at 1800Z. It then tracked northeast across the Gulf of California and entered Mexico over the northern part of the state of Sinaloa near the town of Los Mochis on

September 14th around 1200Z. By this time it had decreased in strength and was a tropical storm with winds of 45 knots and central pressure near 1000 mb.

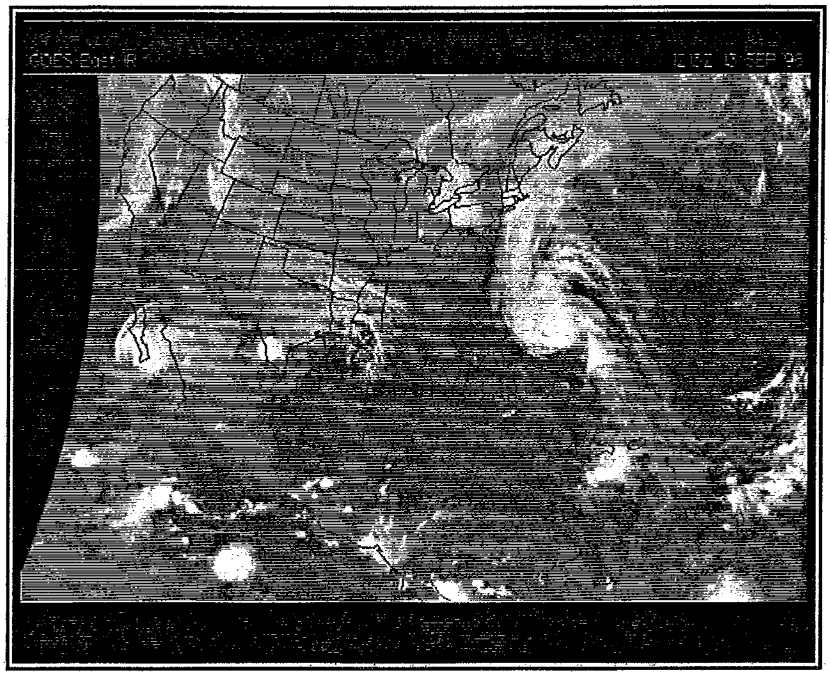

Figure 28 Fausto entering the Gulf of California.

The satellite photographs on Figures 28 and 29 show Fausto as it crossed the tip of Baja California and moved northeast into northern Mexico. Fausto had 60 knot sustained winds with gusts to 75 knots when it crossed San Jose Del Cabo, Mexico and according to Beven (1996), there was one reported death in Baja California. In his preliminary report, Lawrence (1996) noted that this fatality was a San Diego vacationer who was electrocuted when a power line fell at a trailer park near Cabo San Lucas.

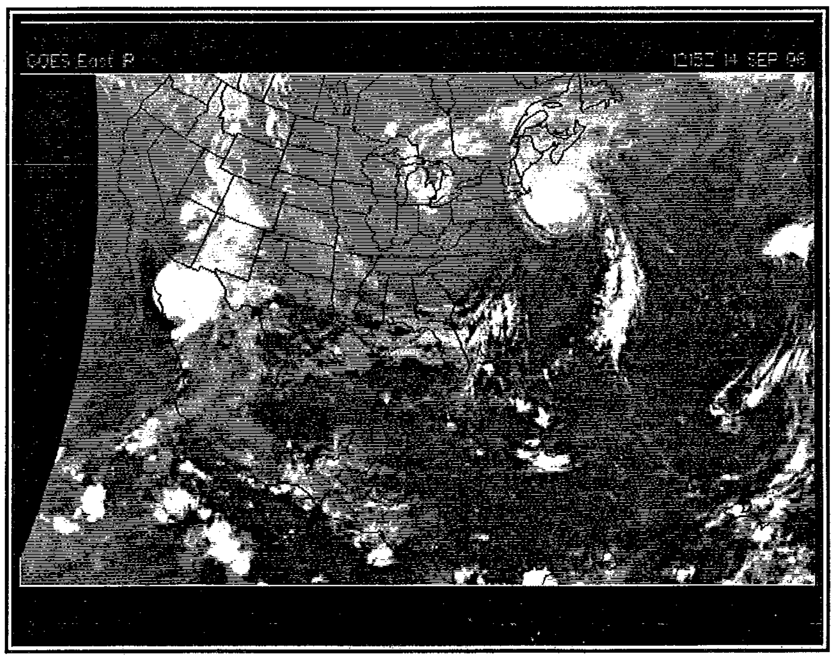

Figure 29 Fausto over northern Mexico moving eastward.

The Associated Press reported that Fausto battered Baja California, downing power poles, smashing windows and disrupting the tourist business at Cabo San Lucas and La Paz. Waves of up to 15 feet walloped Pacific beaches along the southern tip of Baja and yachts were damaged.

There was one report of four inches of rainfall at Cabo San Lucas and heavy rains caused mudslides there. Similar amounts of rain likely occurred inland over northern Mexico although no reports were received to verify these estimates.

Most of the showers were kept east of California by the upper level trough which moved across the southwest during the period from September 13-15.

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/0600	14.8 N	102.7 W	1008	25	T.D.
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/1800	15.8 N	104.3 W	1004	35	T.S.
SEP. 11/0000	16.4 N	105.1 W	1000	45	T.S.
/0600	17.1 N	106.2 W	991	55	T.S.
/1200	17.8 N	107.3 W	982	65	HURRICANE
/1800	18.4 N	108.2 W	973	80	HURRICANE
SEP. 12/0000	19.1 N	108.9 W	960	95	HURRICANE
/0600	19.8 N	109.5 W	955	105	HURRICANE
/1200	20.5 N	110.0 W	955	105	HURRICANE
/1800	21.1 N	110.4 W	958	100	HURRICANE
SEP. 13/0000	21.6 N	110.6 W	962	90	HURRICANE
/0600	22.1 N	110.7 W	968	85	HURRICANE
/1200	22.6 N	110.7 W	973	80	HURRICANE
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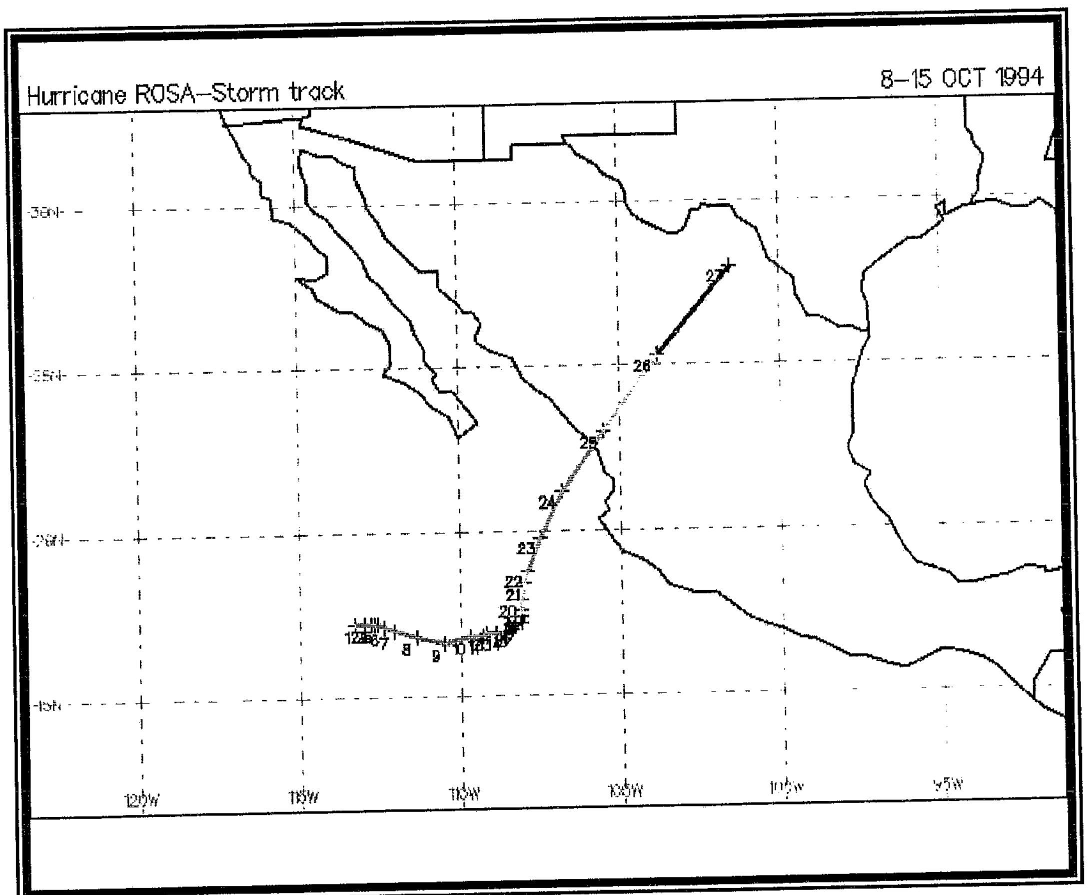

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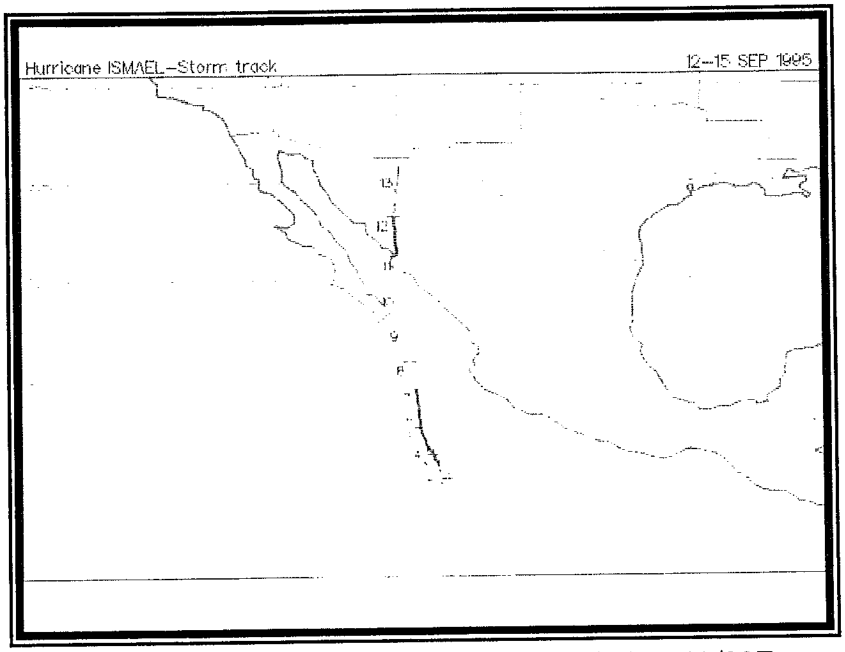

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Surface features showed a prominent thermal low over the California and Arizona border. High temperatures during the period of September 13-15 were mainly in the low 100s in this area. Dew point temperatures increased from the upper 40s to the low to mid 60s as Ismael approached the U.S. border.

At the 500 mb level, a well defined ridge was in place over the southwest U.S. extending into the state of Washington. The long wave trough was situated over the Great Lakes. By September 15th, a trough had developed to the west of California.

Therefore, as Ismael moved into Mexico, the forward motion of the hurricane increased to just under 20 knots as it was steered by the mid and upper level trough to the west, and a deep-layer-mean ridge to the east.

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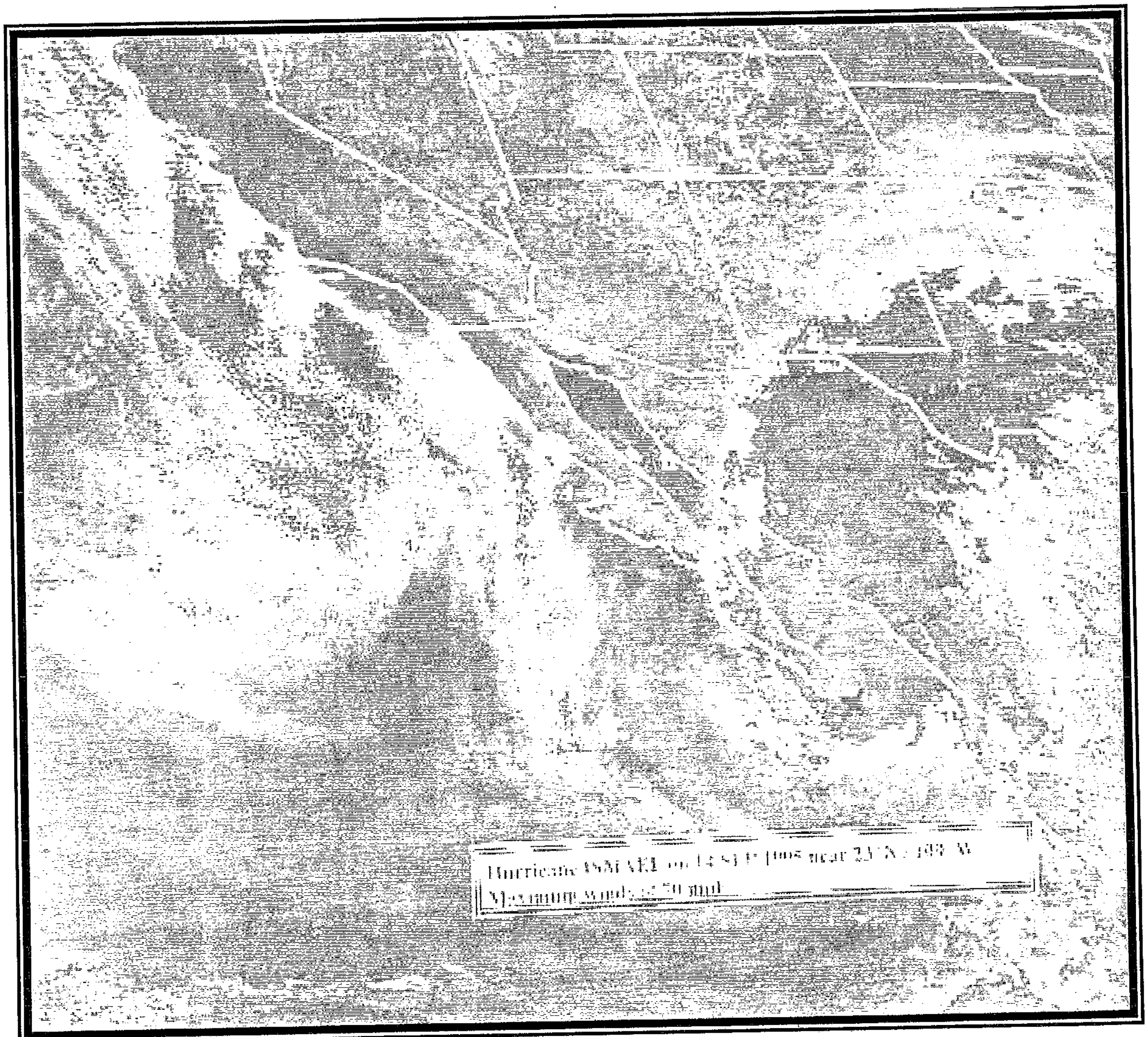

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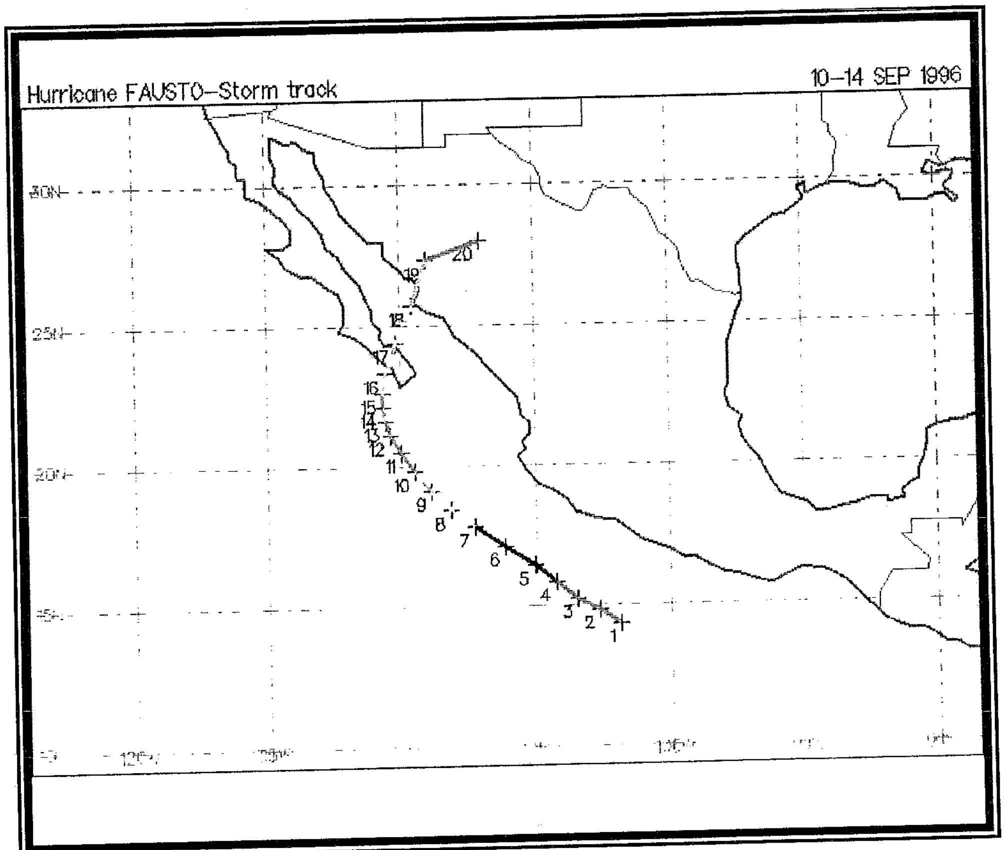

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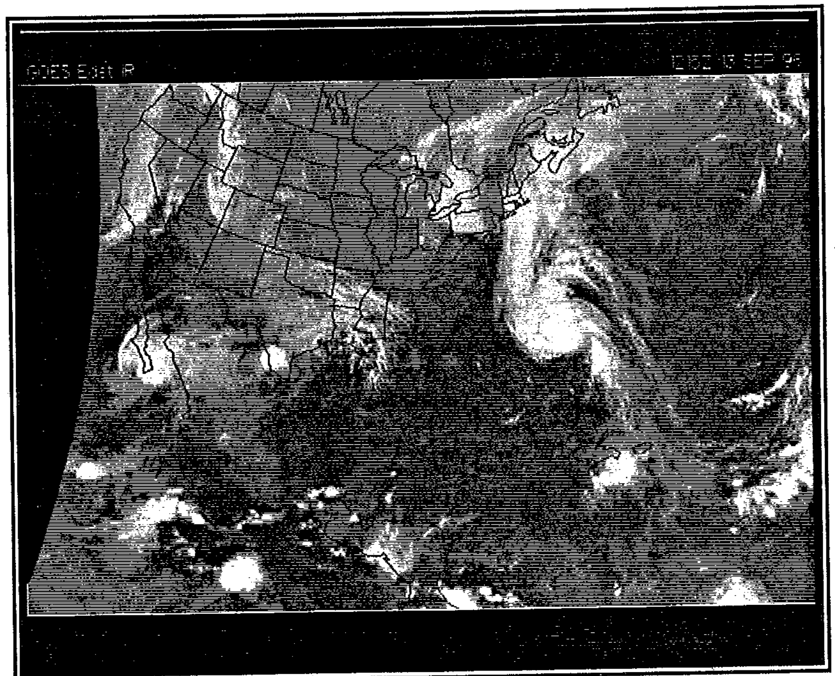

Figure 28 Fausto entering the Gulf of California.

The satellite photographs on Figures 28 and 29 show Fausto as it crossed the tip of Baja California and moved northeast into northern Mexico. Fausto had 60 knot sustained winds with gusts to 75 knots when it crossed San Jose Del Cabo, Mexico and according to Beven (1996), there was one reported death in Baja California. In his preliminary report, Lawrence (1996) noted that this fatality was a San Diego vacationer who was electrocuted when a power line fell at a trailer park near Cabo San Lucas.

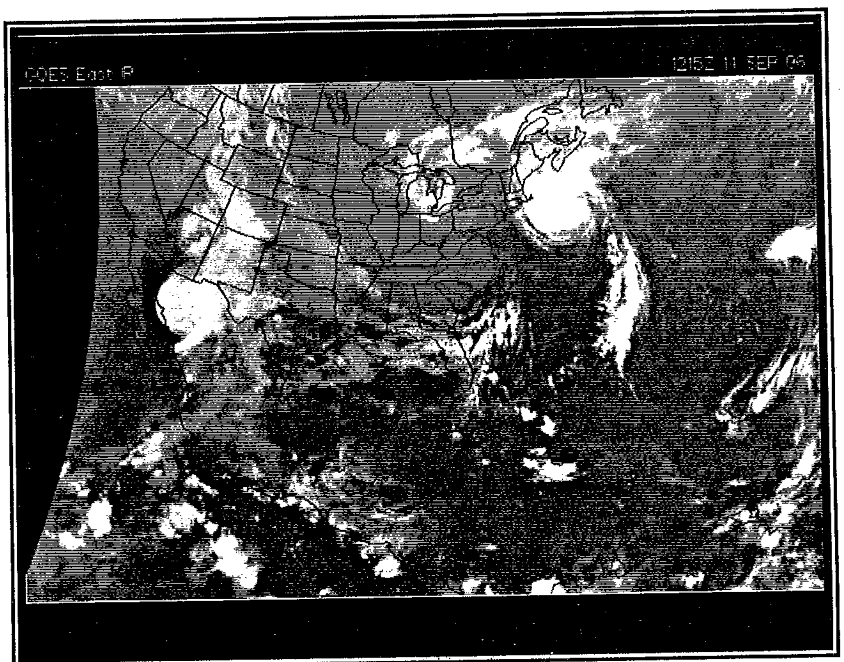

Figure 29 Fausto over northern Mexico moving eastward.

The Associated Press reported that Fausto battered Baja California, downing power poles, smashing windows and disrupting the tourist business at Cabo San Lucas and La Paz. Waves of up to 15 feet walloped Pacific beaches along the southern tip of Baja and yachts were damaged.

There was one report of four inches of rainfall at Cabo San Lucas and heavy rains caused mudslides there. Similar amounts of rain likely occurred inland over northern Mexico although no reports were received to verify these estimates.

Most of the showers were kept east of California by the upper level trough which moved across the southwest during the period from September 13-15.

Table 1996-A provides the best track data for Hurricane Fausto for each 6-hour synoptic time period. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1996-A
BEST TRACK FOR HURRICANE FAUSTO

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 10/0000	14.3 N	101.9 W	1010	25	T.D.
/0600	14.8 N	102.7 W	1008	25	T.D.
/1200	15.2 N	103.5 W	1006	30	T.D.
/1800	15.8 N	104.3 W	1004	35	T.S.
SEP. 11/0000	16.4 N	105.1 W	1000	45	T.S.
/0600	17.1 N	106.2 W	991	55	T.S.
/1200	17.8 N	107.3 W	982	65	HURRICANE
/1800	18.4 N	108.2 W	973	80	HURRICANE
SEP. 12/0000	19.1 N	108.9 W	960	95	HURRICANE
/0600	19.8 N	109.5 W	955	105	HURRICANE
/1200	20.5 N	110.0 W	955	105	HURRICANE
/1800	21.1 N	110.4 W	958	100	HURRICANE
SEP. 13/0000	21.6 N	110.6 W	962	90	HURRICANE
/0600	22.1 N	110.7 W	968	85	HURRICANE
/1200	22.6 N	110.7 W	973	80	HURRICANE
/1800	23.3 N	110.6 W	978	75	HURRICANE
SEP. 14/0000	24.4 N	110.2 W	985	70	HURRICANE
/0600	25.7 N	109.6 W	990	65	HURRICANE
/1200	27.3 N	109.0 W	1000	45	T.S.
/1800	28.0 N	107.0 W	1004	30	T.D.

N. Tropical Storm Ignacio ..... August 17-19, 1997

Tropical Storm Ignacio had a short life over the eastern North Pacific as it developed on August 17th near latitude 18.7°N and 117.9°W and dissipated several days later on August 19th near 28.6°N and 121.9°W. It then became extra-tropical and continued to move due north, eventually affecting sections of central California.

Figure 30 shows the track of Tropical Storm Ignacio.

Surface features on August 17th were normal for the southwest. A north to south elongated thermal low was situated across the California / Arizona border through August 19th.

At the 500 mb level, a trough was entering the northwest portion of the country on August 17th and 18th, progressing east into the Rockies by August 19th.

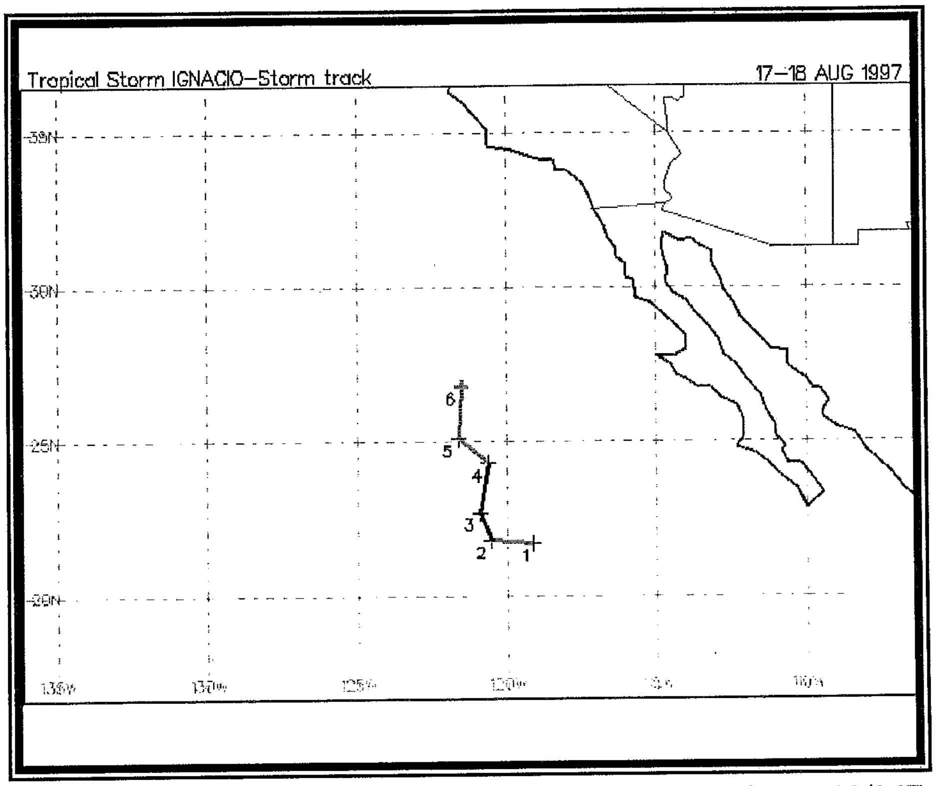

Figure 30 **T.S.** (1) Aug. 18/00Z; **T.D.** (2-6) Aug. 18/06Z - 19/06Z

An upper level ridge kept the weak tropical storm to the west of Baja and southern California.

As another trough pushed into the west coast on August 19th however, the flow became favorable for steering of Ignacio into the coastal sections of San Francisco.

Ignacio became extra-tropical around mid morning of August 19th, and its impact on the southwest, in particular the central California coast, was much different than other tropical systems.

In the case of Ignacio, moisture was available with the system, and some rainfall occurred along the coastal sections of central California. However, its adverse effects were in creating stronger winds in an environment where wildfires were occurring.

Gale force winds were recorded and inland over the San Joaquin Valley, winds of 40 mph with stronger gusts was responsible for wildfires to burn out of control.

This same condition was evident over other sections of southern California, as a tighter gradient increased winds that fanned fires.

According to Rappaport (1997), rainfall totals were generally 0.5 - 1.25 inches over coastal areas of central California, with a maximum of 2.17 inches recorded at Three Peaks, in the coastal range about 100 miles south of San Francisco.

About one inch of rain fell in San Francisco, which was more than had previously been recorded for the entire month of August since records began in 1850.

The satellite photograph on Figure 31 shows Ignacio as it was moving north across latitude 24.0°N on August 18th.

As it approached the west coast of California near San Francisco on August 20 (Figure 32), its impact was to tighten the gradient flow over the area.

Figure 31 "Ignacio" moving almost due north on August 18.

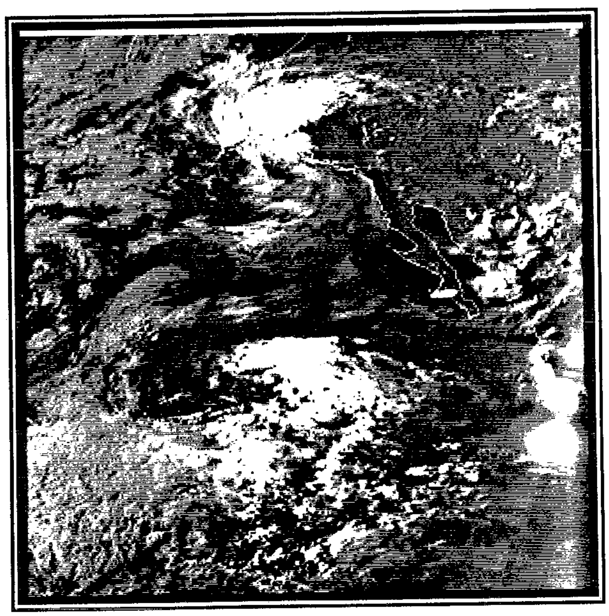

Figure 32 Remnants of "Ignacio" near San Francisco on August 20.

Table 1997-A provides the best track data for Tropical Storm Ignacio for each 6-hour synoptic time. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1997 - A
BEST TRACK FOR TROPICAL STORM IGNACIO

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
AUG. 17/0000	18.7 N	117.9 W	1008	25	T.D.
0600	19.6 N	118.7 W	1006	30	T.D.
1200	20.4 N	119.4 W	1005	35	T.S.
1800	21.2 N	120.1 W	1006	35	T.S.
AUG. 18/0000	22.1 N	120.7 W	1006	35	T.S.
0600	23.2 N	121.7 W	1007	30	T.D.
1200	24.5 N	121.6 W	1008	30	T.D.
1800	25.9 N	121.8 W	1008	25	T.D.
AUG. 19/0000	27.2 N	121.8 W	1009	25	T.D.
0600	28.6 N	121.9 W	1009	25	T.D.
1200	30.0 N	121.8 W	1010	25	Extratropical
1800	31.7 N	121.7 W	1010	20	Extratropical
AUG. 20/0000	33.3 N	121.6 W	1010	20	Extratropical
0600	35.0 N	121.5 W	1012	20	Extratropical

O. Hurricane Linda ..... September 9-17, 1997

The 1997 hurricane season in the eastern North Pacific was a significant one because of the increased focus on a strong El Niño event which was creating dramatic anomalies in sea surface temperatures over the equatorial Pacific. A total of 17 tropical systems developed, and although not directly impacting the southwestern U.S. with significant damage, Hurricane Linda did create excitement and was responsible for changing a long standing dry pattern over southern California. Linda became the strongest hurricane on record in the eastern Pacific when it reached 185 mph on September 12 when it was approximately 145 miles southeast of Socorro Island.

Figure 33 shows the track of Hurricane Linda.

The synoptic pattern that was in place through about September 13th was the same that existed for several weeks. It was essentially a strong upper level high over the central U.S. and an upper level trough off the west coast.

By September 14th, the southern edge of the upper level trough extended to about 30N and 128W, causing concern that this steering would capture Linda and recurve it northeast.

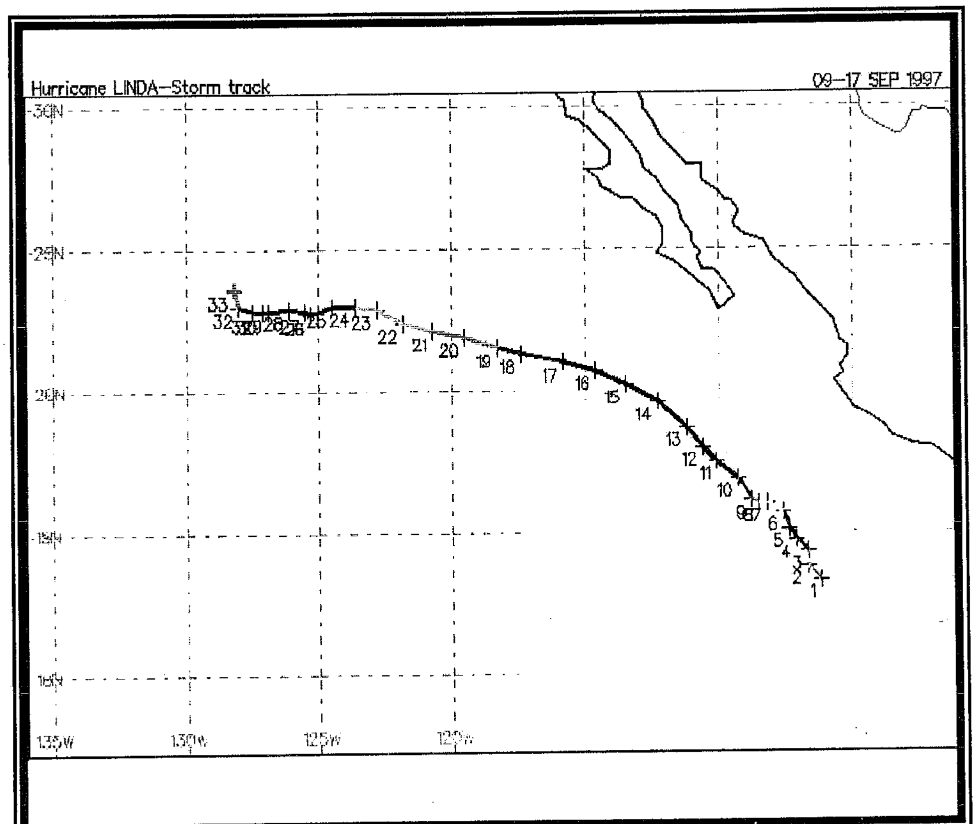

Figure 33 ..... **T.D.** (1-2) Sep. 09/12Z-18Z; **T.S.** (3-6) Sep. 10/00Z - 18Z; **HUR** (7-24) Sep. 11/00Z - 15/06Z; **T.S.** (25-30) Sep. 15/12Z - 17/00Z; **T.D.** (31-33) Sep. 17/06Z-18Z.

Hurricane Linda began to quickly weaken on September 14th as it entered an area with cooler waters. At this point, the deep layer mean models where still showing a continuing northward track but with Linda being much weaker, the steering was dictated more by the mid and low layer flow. Thus a west northwesterly track continued for the next several days.

Linda dissipated about 1,000 miles west of the southern tip of Baja California generating large waves and swells which reached northern Baja California and the southern California coasts. Five men were swept off a jetty in Newport Beach by the large 18 foot waves. A passing boater rescued them but four were injured, one critically, after nearly drowning. Similar waves were reported at Huntington Beach.

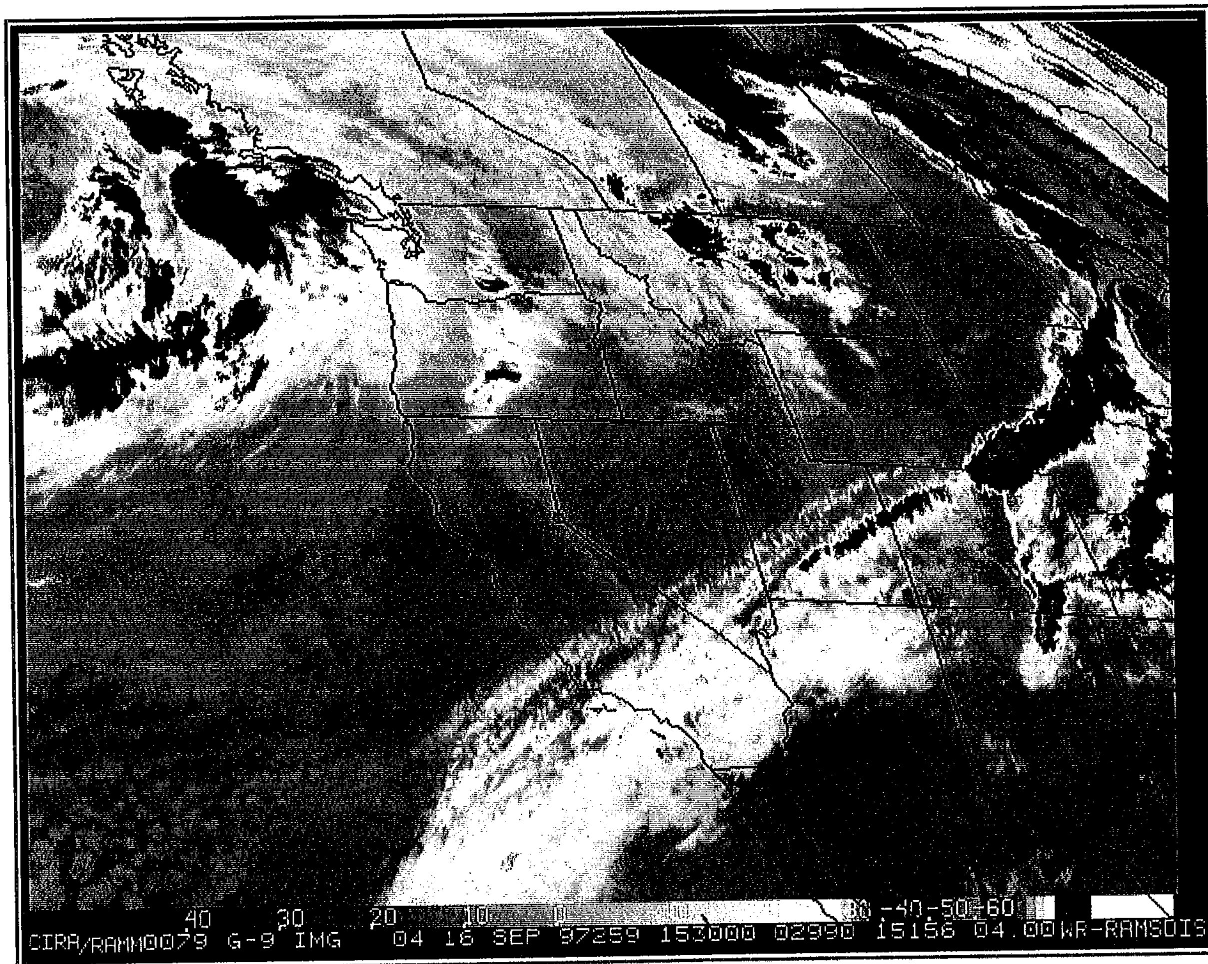

Figure 34 ..... Moisture from remnants of Hurricane Linda stream northeast across southern California into northern Arizona on September 16, 1997.

The satellite photograph on Figure 34 shows the moisture streaming northeast from Linda across southern California on September 16, 1997. Linda had already brought scattered showers in the mountains and deserts on September 15th.

Storm totals were generally less than 0.25 inch. The 0.02 inch rain that was recorded at Lindbergh Field was enough to break a streak of 164 days without rain, a span which extended from April 4, 1997 through September 14, 1997. Other rainfall totals in southern California included 0.52 inch at Palomar Mountain, 0.15 at Escondido, and 0.12 at Del Mar.

Table 1997-B provides the best track data for Hurricane Linda beginning with the genesis area, then for each 6-hour synoptic time period after September 12. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1997-B
BEST TRACK FOR HURRICANE LINDA

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 09/1200	12.4 N	104.7 W	1007	25	T.D.
SEP. 10/0000	13.5 N	106.1 W	1005	35	T.S.
SEP. 11/0000	15.4 N	107.4 W	987	65	HURRICANE
SEP. 12/0000	16.6 N	109.1 W	906	155	HURRICANE
/0600	17.1 N	109.6 W	902	160	HURRICANE
/1200	17.7 N	110.3 W	903	155	HURRICANE
/1800	18.4 N	111.0 W	905	150	HURRICANE
SEP. 13/0000	19.1 N	111.9 W	906	145	HURRICANE
/0600	19.7 N	113.0 W	910	145	HURRICANE
/1200	20.2 N	114.1 W	915	140	HURRICANE
/1800	20.6 N	115.3 W	921	135	HURRICANE
SEP. 14/0000	21.0 N	116.5 W	935	125	HURRICANE
/0600	21.3 N	117.8 W	946	110	HURRICANE
/1200	21.6 N	119.0 W	950	95	HURRICANE
/1800	21.9 N	120.1 W	959	80	HURRICANE
SEP. 15/0000	22.2 N	121.1 W	962	75	HURRICANE
/0600	22.5 N	122.1 W	980	65	HURRICANE
/1200	22.7 N	123.1 W	994	55	T.S.
/1800	22.8 N	124.0 W	997	50	T.S.
16/0000	22.8 N	124.7 W	999	45	T.S.
/0600	22.8 N	125.3 W	1000	40	T.S.
/1200	22.8 N	125.9 W	1001	35	T.S.
/1800	22.9 N	126.4 W	1001	35	T.S.
17/0000	22.9 N	126.8 W	1002	35	T.S.
/0600	23.0 N	127.2 W	1003	30	T.D.
/1200	23.2 N	127.6 W	1004	30	T.D.
/1800	23.5 N	128.0 W	1006	30	T.D.

P. Hurricane Nora ..... September 22-26, 1997

Hurricane Nora was the third tropical cyclone which formed in the East North Pacific and thrived on the anomalously warm sea surface temperatures that had spread well north into coastal sections of Baja California and southern California as a result of a strong El Niño that developed across the equatorial Pacific.

Garza, et al (1995) observed similar pockets of warm water that sustained and produced explosive strengthening when tropical cyclones moves across such SST anomalies in the Central Pacific. Nora made landfall early on the September 25th at Punta Euguenia in Baja California. It crossed Baja and made landfall again about 50 miles south southeast of San Fernando as it tracked northeast, entering the United States just to the west of Yuma, Arizona.

Figure 35 shows the best track of Hurricane Nora.

Rappaport (1997) attributed the steering of Nora to an omega-like blocking pattern that developed over the southwest during the end of September. This resulted in a weakening in the height pattern to the north of Nora and eventually a trough with a cut-off low developed to the northwest of the hurricane.

The sea surface environment resident ahead of all three tropical systems (Ignacio, Linda, and Nora) was within the required temperatures for sustaining the strength of the cyclones, especially as long as they tracked close to the coastal sections north of latitude 25N.

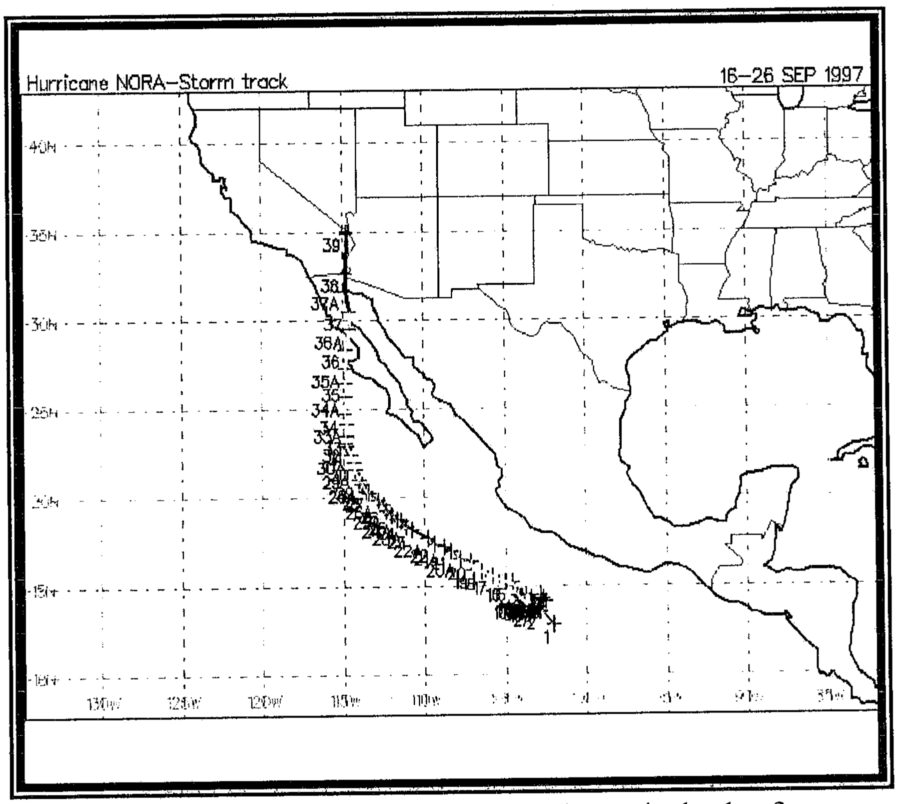

Figure 35 ..... Hurricane Nora formed rapidly on the heels of Hurricane Linda in an area where above normal sea surface temperatures existed..

Although winds from "Nora" did not significantly impact any areas in southern California, the rainfall that fell was noteworthy. The doppler radar was used to identify the highest reflectivities of 49 DBZ, which were found at about 1800Z on September 25th, which was the time of the heaviest rain. These reflectivities were isolated and there were more widespread returns of about 35 DBZ. The radar wind data was found to be extremely reliable. The September 25th radar VWP and the 12Z Miramar Upper Air sounding winds agreed very well. Both showed veering with height which would imply warm air advection - no surprise with an approaching system.

In San Diego County, the storm total rainfall Mt. Laguna was 4.70 inches, while Ranchita received 2.52 inches for the two day period. Heaviest rainfall occurred on September 25th from the period beginning at 3:00 am and continuing through near midnight on that day. Other reports included: San Diego Lindbergh Field which received .80 inches of rain, and 1.10 inches of rain recorded at the San Diego Weather Service Office in Rancho Bernardo.

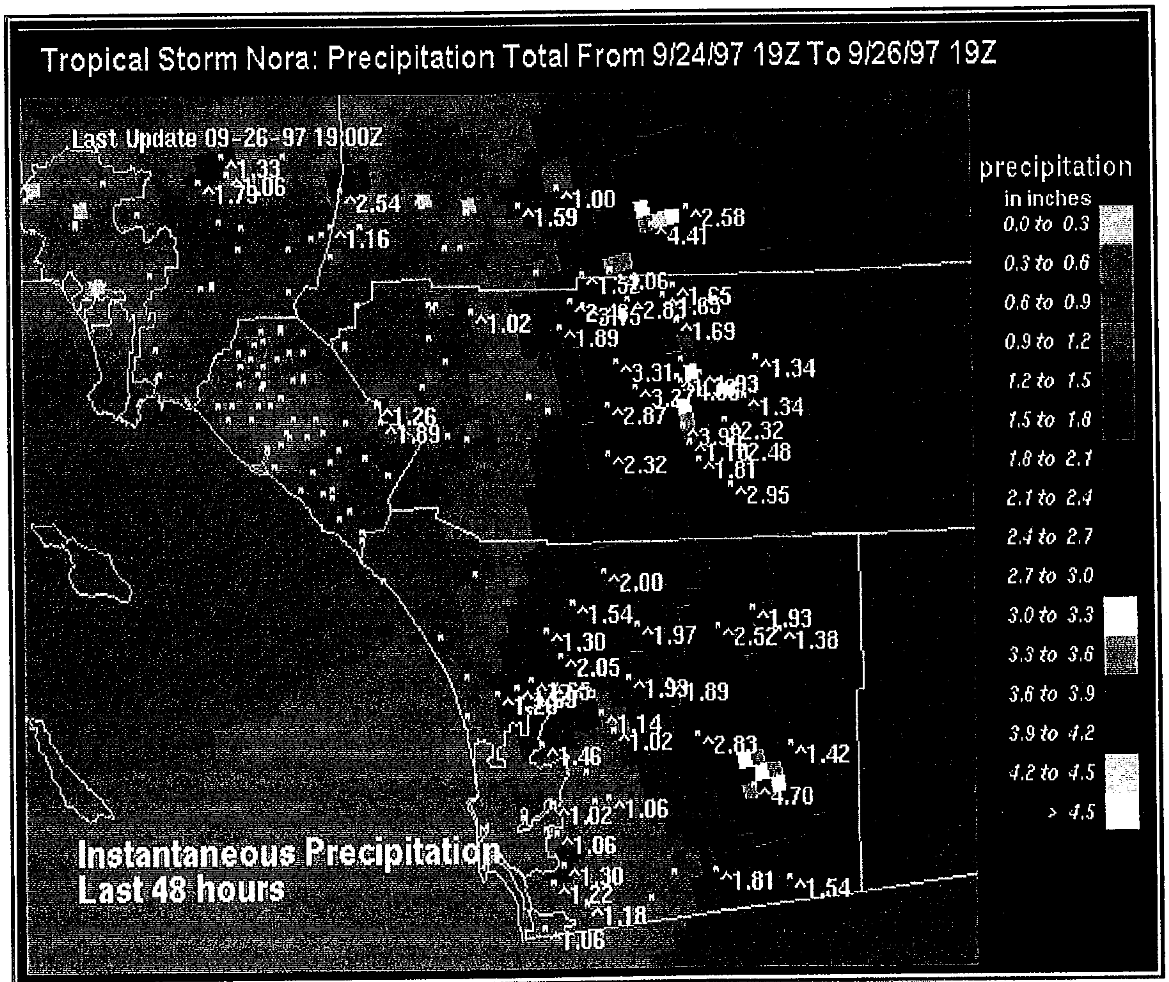

Figure 36 ... Precipitation totals for 48 hour period as Nora moved northeast near Yuma.

Additional rainfall totals were: Brown Field 0.89 inch, Imperial Beach 1.35 in., Chula Vista 1.33 in., Montgomery Field 1.08 in., National City 1.19 in., Miramar 1.15 in., Poway 1.49 in., Escondido 1.84 in., El Cajon 1.06 in., Alpine 1.41 in., Oceanside 0.71 in., Del Mar 1.08 in., and Borrego 1.79 in.

Figure 36 only shows rainfall reports which were automatically received from the ALERT network. Note that rainfall over the mountains and deserts of San Diego County was fairly uniform, with most areas receiving just over 1 inch to close to 2 inches, and isolated pockets of heavier rainfall seen in the higher elevations.

Farther north in Riverside County and San Bernardino County, rainfall was also significant in many areas of the deserts and mountains. In Riverside: Palm Springs recorded 1.73 in., Thermal 1.98 in., Indio 1.55 in., Beaumont 0.94 in., Riverside 0.44 in., Hemet 2.88 in., Idyllwild 2.86 in., Banning Bench 3.07 in., and Upper Tahquitz Creek 3.15 in.

In San Bernardino County similar reports were received: Hesperia 0.91 in., Twenty-nine Palms 3.07 in., Crestline 0.81 in., Upper Morongo Creek 3.61 in., Raywood Flat 3.45 in.

Orange County recorded similar rainfall amounts, and with the exception of the higher amounts at the higher elevations over the eastern portion of the county, most areas averaged 1-2 inches of rain.

On Thursday, September 25, 1997, beginning at around 11:00 am and continuing throughout the afternoon, steady rain was beginning to cause minor flooding in parts of San Diego County and Riverside County near Indio and Palm Springs. There was some minor flooding in the city of Palm Springs with some intersections blocked. Indio received enough rain to cause the closure of several roads in and outside the city limits.

San Diego Flood Control verified that the most prominent flooding was occurring in the North County near Escondido Creek where flood waters were almost up to the Country Club Road. Areas around Harmony Grove were also rising at a rate of 2 feet per 15 minutes. Corey Road was closed near the Spring Valley Creek which was flowing 1 1/4 feet over the road.

In Los Angeles and Ventura Counties, heaviest rain recorded was 0.50 to 0.75 inch along the coastal sections and 1.00 to 1.75 inches in the mountains.

In Arizona, 11.97 inches of rain fell at the 5,700 foot level in the Harquahala Mountains. Ludwig (1998) noted that the 24 hour rainfall at Yuma was 3.83 inches with higher amounts occurring in the southwest part of the state. Some significant reports included: Yarnell Hill with 6.26 inches, Bagdad and Thumb Butte Tank...each with 5.75 inches, Mayer with 5.06 inches, Crown King with 4.79 inches, Hualapai Mountain with 4.50, Centenial Wash with 4.21, Tiger Wash Fan with 4.17, and Gladden with 4.02. Numerous other areas had storm totals of 2-3 inches.

Nora resulted in slippery road conditions in San Diego County and the impact was felt mostly on the freeways. The California Highway Patrol handled more than 260 accidents by late Thursday afternoon on September 25, and dispatchers logged 51 wrecks in one hour alone, from 1 to 2 p.m., and 47 more the next hour. The rains turned San Diego County roadways treacherously slick, with accidents claiming two lives and causing numerous serious accidents. A Camp Pendleton Marine died in Oceanside when the car in which he was riding crashed head-on with a van on North Coast Highway near 8th Street. Five other people were hospitalized with injuries in another collision.
In Pala, a woman died when she lost control of her Mercedes on a curve of northbound Pala Temecula Road near Rancho Heights Road and skidded into a tree at 9:25 am.

Flooding temporarily closed a road into Borrego Springs, causing a Chevron station to postpone fuel service until its supply tanker could get through.

Waves of 3 to 9 feet pounded the beaches from San Diego to Del Mar, waves of up to 20 feet high battered Orange County's Seal Beach before dawn on Thursday at high tides, causing local flooding. A high surf advisory was in effect for Los Angeles and Orange County beach areas. Firefighters used a kayak to bring sandbags to beach homes swamped by the waves. Bulldozers were called in to build berms and cut channels to drain the water back out to sea. Heavy surf sent waves up to 18 feet high thundering into the Wedge at Newport Beach

In Mexico, reports indicated two dead and hundreds homeless. One of the dead was electrocuted by a downed power line in Mexicali. A diver harvesting sea urchins off the coast of the San Quintin Valley died from nitrogen narcosis, "the bends", in a death that authorities there blamed partly on strong underwater currents created by Nora.

San Felipe, on the coast of the Sea of Cortez, suffered heavy damage and flooding. One entire community of working-class families, Arroyo de Santa Catarina, was driven out by flood waters that destroyed or damaged scores of dwellings. Approximately 350 to 400 residents were homeless. The highway between Mexicali and San Felipe was cut by flash floods that turned normally dry streambeds and low-lying dips called "vados" into churning torrents.

Table 1997-C provides the best track data for Hurricane Nora beginning with the genesis area, then for each 6-hour synoptic time period after September 22. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1997-C BEST TRACK FOR HURRICANE NORA					
DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 16/0600	12.7 N	101.7 W	1004	25	T.D.
SEP. 17/0000	13.9 N	102.3 W	1000	40	T.S.
SEP. 18/0000	14.3 N	102.9 W	990	55	T.S.
SEP. 19/0000	14.3 N	103.9 W	972	90	HURRICANE
SEP. 20/0600	14.8 N	104.5 W	985	70	HURRICANE
SEP. 21/1200	15.8 N	106.7 W	979	75	HURRICANE
SEP. 22/0000	17.7 N	109.7 W	952	110	HURRICANE
/0600	18.0 N	110.5 W	953	110	HURRICANE
/1200	18.5 N	111.2 W	955	110	HURRICANE
/1800	18.9 N	111.8 W	957	105	HURRICANE
SEP. 23/0000	19.3 N	112.3 W	961	95	HURRICANE
/0600	19.8 N	112.9 W	973	90	HURRICANE
/1200	20.2 N	113.3 W	983	80	HURRICANE
/1800	20.7 N	113.7 W	980	70	HURRICANE
SEP. 24/0000	21.5 N	114.1 W	979	75	HURRICANE
/0600	22.3 N	114.5 W	979	75	HURRICANE
/1200	23.2 N	114.8 W	979	75	HURRICANE
/1800	24.2 N	114.8 W	979	75	HURRICANE
SEP. 25/0000	25.8 N	114.8 W	979	75	HURRICANE
/0600	27.5 N	114.8 W	981	75	HURRICANE
/1200	29.5 N	114.8 W	984	65	HURRICANE
/1800	31.7 N	114.9 W	990	55	T.S.
SEP. 26/0000	34.0 N	114.7 W	997	30	T.D.
/0600	36.1 N	114.1 W	1004	25	Dissipating

Q. Tropical Storm Frank ..... August 6-9, 1998

The 1998 East Pacific Hurricane season ended with a total of eleven (11) named storms. While the majority developed between latitude 10°N and 18°N and between longitude 96°W and 107°W, the majority tracked westward with no significant impacts to land. The exception was Tropical Storm Frank, which threatened the west central coastal sections of Baja California and had moisture spill into portions of the southwest United States.

Figure 37 shows the storm track of Tropical Storm Frank.

Tropical Storm Frank developed near 18°N on August 6th. Surface features to the north of Frank showed an elongated trough extending south through most of California, then south into the central portions of Baja California. This feature was evident for several days, losing its identity by August 9th as Frank approached Punta Abreojos Mexico, in Baja California. Throughout the four day period, a surface High over the four corners area maintained a south and southeast flow over Arizona and southern California.

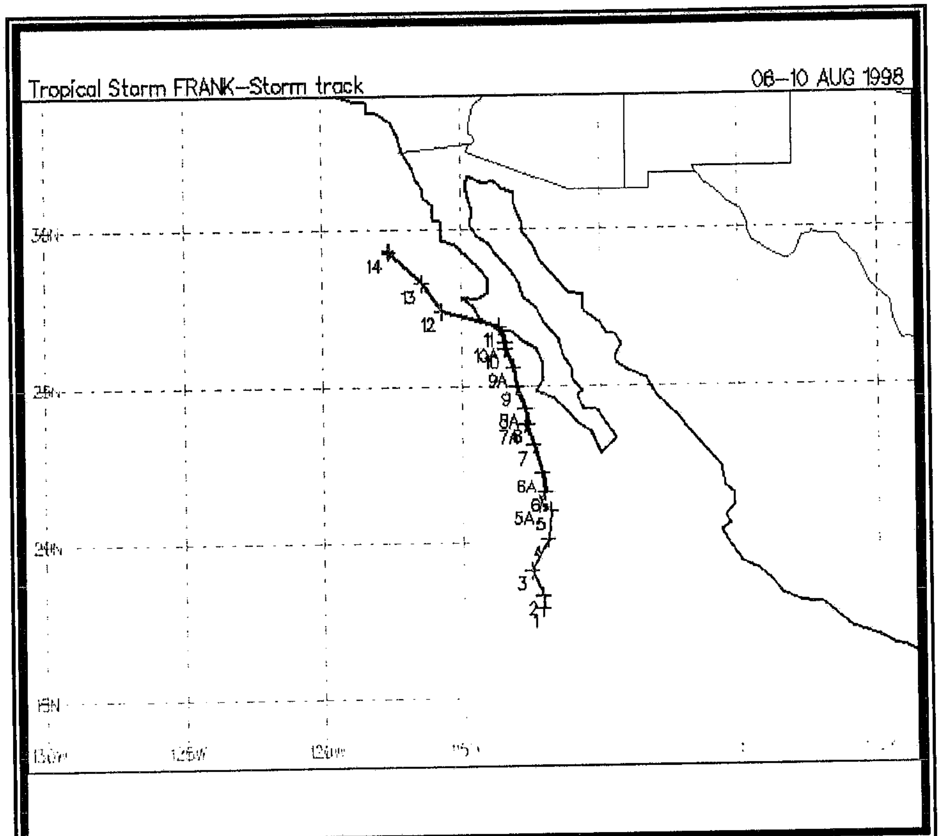

Figure 37 ... **T.D.** (1-6) Aug. 06/21Z - Aug. 08/00Z; **T.S.** (7-10) Aug. 08/06Z - 09/06Z; **T.D.** (11-14) Aug. 09/12Z - 10/00Z.

At the 500 mb level, the flow was not favorable for direct northward movement but Frank was able to curve to the northwest once it approached the coastal sections of Baja California. This westward drift forced it to move over colder sea surface temperatures and Frank quickly lost strength, finally dissipating early on August 10th.

The satellite picture on Figure 38 shows "Frank" early on August 9^{th} when it was located about 400 miles south of San Diego. Moisture from the system was penetrating well north into southern California and western Arizona. At this time and for the following 6-12 hours, doppler radar was indicating a wide band of moderate showers from Ensenada northeast through Yuma, and fragmented bands across San Diego County north in to Riverside County.

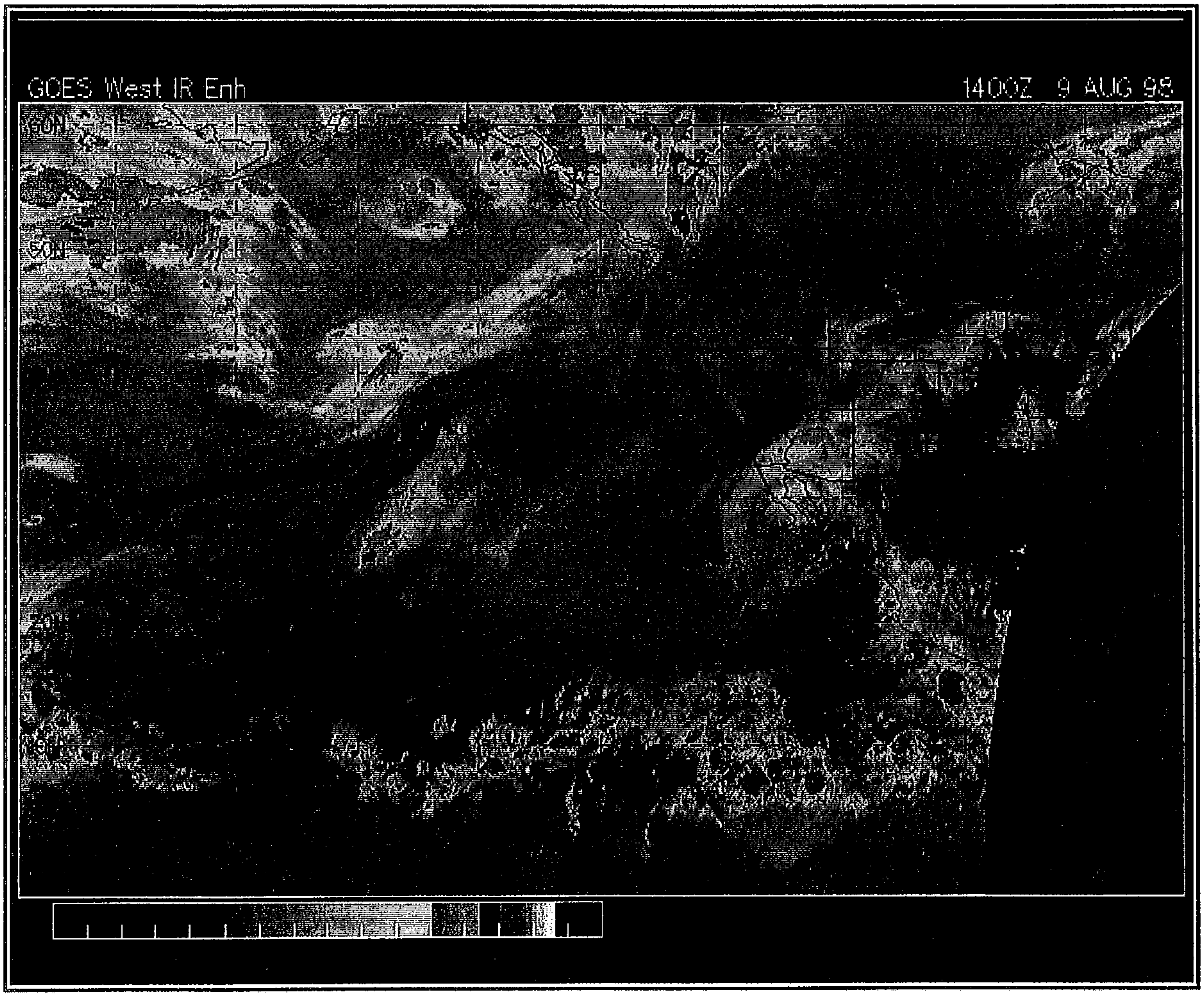

Figure 38 ..... Enhanced Infrared satellite photograph on August 9, 1998 at 1400Z.

Showers and thunderstorms produced by Frank occurred over northern Baja and southern California on August 9^{th} and 10th. For southern California, shower activity was scattered and coastal areas generally received close to one tenth of an inch (Coronado .10 inch; Brown Field .11 inch; Chula Vista .15 inch), inland areas received up to a third of an inch (Hemet .35 inch; Temecula .30 inch), mountain areas one half to three quarters of an inch (Big Bear Lake .53 inch; Idyllwild .72 inch; Palomar Mountain .76 inch), and desert areas less than a third of an inch (Palm Springs .29 inch; Borrego .12 inch) with the exception of Indio which received .55 inch.

The best track for Tropical Storm Frank can be found in Table 1998-A. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1998 - A
BEST TRACK FOR TROPICAL STORM FRANK

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
AUG. 06/2100	17.9 N	112.1 W	1006	25	T.D.
AUG. 07/0000	18.1 N	112.1 W	1006	25	T.D.
0600	18.7 N	112.3 W	1006	25	T.D.
1200	19.6 N	112.2 W	1006	25	T.D.
1800	20.6 N	111.8 W	1005	25	T.D.
AUG. 08/0000	21.2 N	112.2 W	1003	30	T.D.
0600	22.2 N	112.1 W	1003	35	T.S.
1200	23.8 N	112.7 W	1003	35	T.S.
1800	24.3 N	112.7 W	1001	35	T.S.
AUG. 09/0000	25.6 N	113.1 W	1003	35	T.S.
0600	26.4 N	113.4 W	1003	35	T.S.
1200	27.2 N	114.0 W	1006	30	T.D.
1800	27.8 N	116.0 W	1009	30	T.D.
AUG. 10/0000	28.8 N	117.3 W	1010	25	T.D.

R. Hurricane Isis ..... September 1-3, 1998

The second tropical system to affect the southwest in 1998 was Isis. Isis developed rapidly in a favorable area where a pocket of sea surface temperatures were still between 25°C and 27°C. The tropical system which developed on the first day of September, only took approximately 30 hours to intensify to minimal hurricane strength.

Figure 39 shows the track of Hurricane Isis.

Synoptic scale features included a rather broad surface high over the Rocky Mountain states which by September 3rd extended well into west Texas. This helped to maintain an east and southeast flow across most of the southwest United States.

At the 500 mb level, winds were also east and southeast with winds of 15-25 knots.

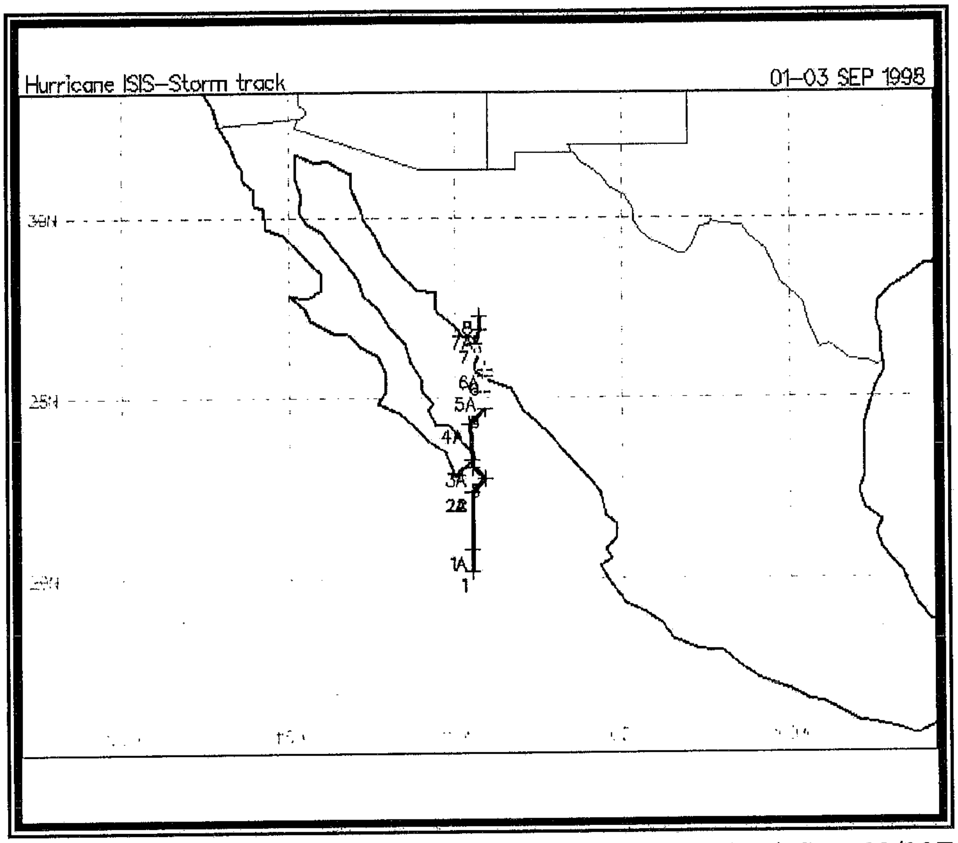

Figure 39 ...... **T.S.** (1-4) Sep. 01/21Z - 02/18Z; **HUR**. (5-6) Sep. 03/00Z - 06Z; **T.S.** (7-8) Sep. 03/12Z-15Z

Isis developed in an area over the eastern Pacific about 180 miles south-southeast of Cabo San Lucas on September 1. During the next couple of days, Isis tracked almost due north brushing across the southeast tip of Baja California through the towns of Los Frailes and Los Barriles as it then crossed the Gulf of California before making landfall near Los Mochis.

Isis entered a favored area which is impacted by tropical systems almost annually, and which is within the capture zone for existing synoptic features to direct rich tropical moisture north across northern Mexico, then westward into portions of Arizona and southern California.

The satellite photograph in Figure 40 shows the extensive areas of moisture which accompanied Isis as it tracked north. At the time of this photograph, the center of Isis was entering the Gulf of California, about 40 miles east of San Jose del Cabo. Heavy rains of 4-6 inches occurred over the southern tip of Baja and also over sections of Mexico along and west of the Sierra Madre Occidental mountains. Flooding and mudslides occurred but no reports of fatalities were received.

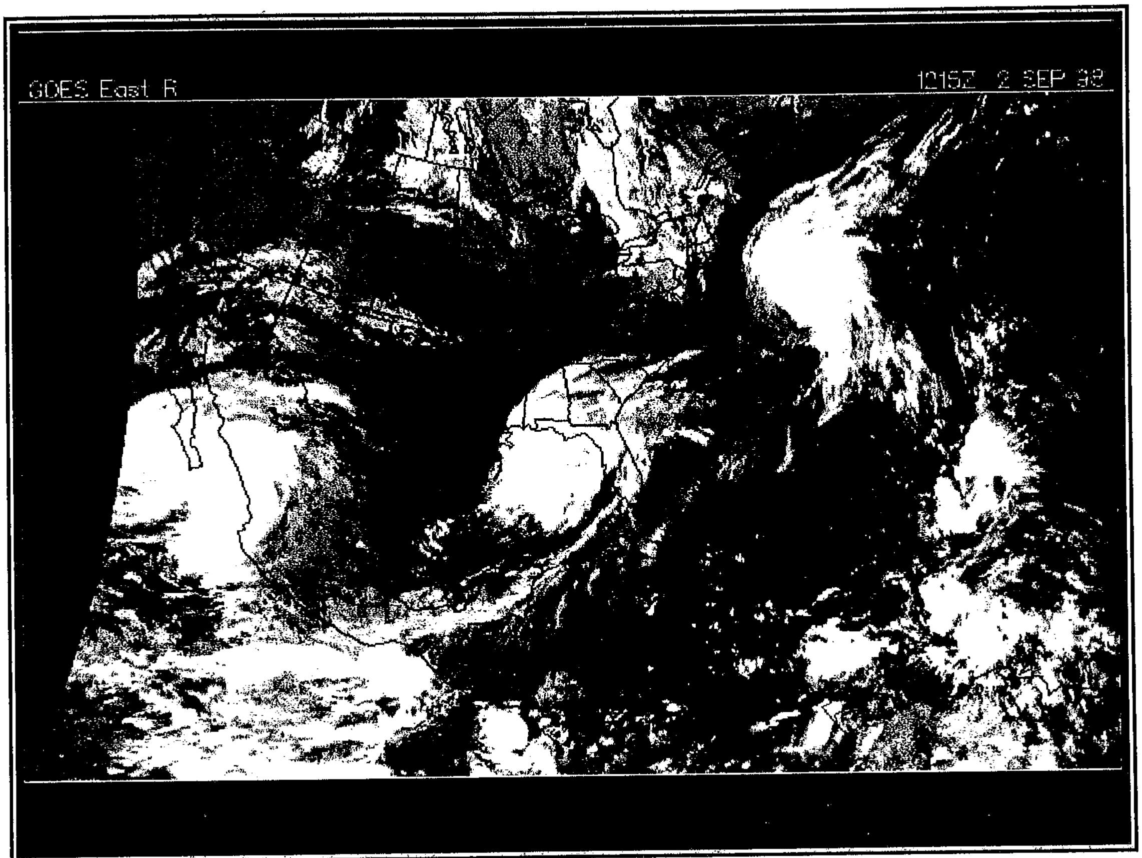

Figure 40 .... Hurricane Isis entering the Gulf of California on September 2, 1998.

Over California, rains from Isis was minimal, with rainfall generally less than one quarter inch across the entire southern areas, not extending farther north than Orange and Riverside Counties. Similar light amounts were recorded over Arizona.

The best track for Hurricane Isis can be found in Table 1998-B. The table provides the latitude and longitude points, maximum sustained wind speeds in knots, the pressure in millibars, and the category for each time listed.

TABLE 1998 - B
BEST TRACK FOR HURRICANE ISIS

DATE/TIME (Z)	LAT.	LON.	PRES (MB)	MAX WINDS (KT)	CATEGORY
SEP. 01/2100	20.2 N	109.5 W	997	45	T.S.
SEP. 02/0000	20.8 N	109.5 W	995	45	T.S.
0600	22.4 N	109.5 W	990	60	T.S.
1200	23.1 N	109.5 W	990	60	T.S.
1800	24.3 N	109.6 W	990	60	T.S.
SEP. 03/0000	25.2 N	109.2 W	990	65	HURRICANE
0600	25.8 N	109.1 W	990	65	HURRICANE
1200	26.9 N	109.3 W	996	45	T.S.
1500	27.3 N	109.3 W	998	45	T.S.

5. Summary and Conclusions

Tropical cyclone climatological records show that a total of 102 systems have impacted the southwestern United States during the period from 1900 - 1998. This total suggests that initial studies which reported that at least one tropical cyclone affects the area each year is still valid.

These records showed that the earliest tropical system to affect the southwest was Hurricane Boris on June 2-8, 1990, whereas before this study, Hurricane Celia (June 25-30, 1980) had held that honor. The latest that a tropical storm affected the area was the Tropical Cyclone which occurred October 22-25, 1925. To date, possibly the most destructive tropical system to impact the southwest was Tropical Storm Kathleen in 1976.

In updating the tropical cyclone climatology, it was found that the month for greatest frequency of occurrence of a system that might impact the southwest is September. The following figure shows the monthly total for the period from 1900 - 1998. Of the 102 total tropical systems that have impacted the area, 97 of these occurred during the months of August, September and October.

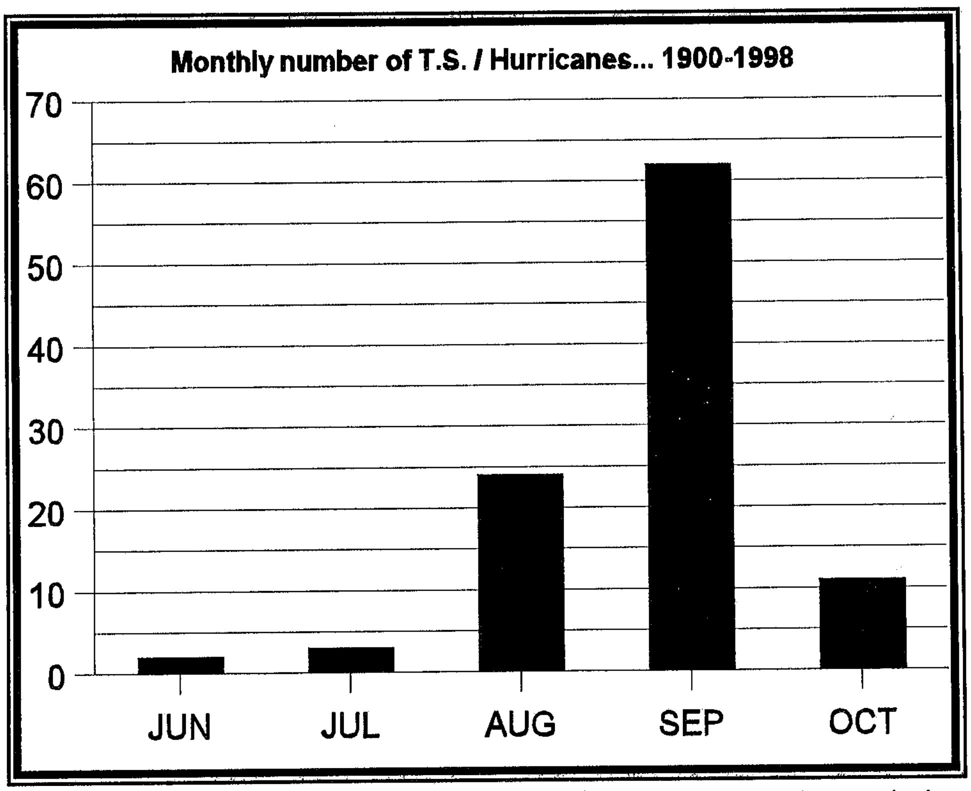

Figure 41 ..... Tropical storms / hurricanes impacting the southwest during the period from 1900 - 1998. Monthly totals in the figure include: June = 2; July = 3; August = 24; September = 62; October = 11.

During the past 30 years the Climate Prediction Center identified the following years which indicate the year that the warm episode began: 1969, 1972, 1976, 1982, 1986, 1991, 1994, 1997. Although it was shown that during El Niño years, there is a well defined increase in activity, no solid relationship could be seen outside of strong warm events.

By using the warm episode beginning year and including the following year for each, it can be shown that three El Niño episodes in the last 30 years resulted in a significant increase in tropical cyclone paths that impacted the southwest.

El Niño years	Total tropical systems
1976-77	6
1982-83	7
1997-98	5

Undoubtedly, this is a result of favorable sea surface temperatures along the west coasts of Baja into southern California during these episodes which helps support the life of the tropical systems which are caught up in favorable synoptic scale conditions.

Once developed, forecasting the tracks of the tropical systems is still a difficult task using today's computer models. Since it is rare that a tropical system will approach the U.S. with much strength, forecasters may need to look at low and mid layer mean winds which might help in identifying the right track of the decaying systems.

Forecasters over the southwest will continue to become more attuned to tropical cyclones and the potential impacts which these systems pose. By noting the history of past significant events, the task of making educated decisions on impacts of similar events will help to provide improved products and services to emergency managers and flood control and water resource managers in the future.

6. Acknowledgments

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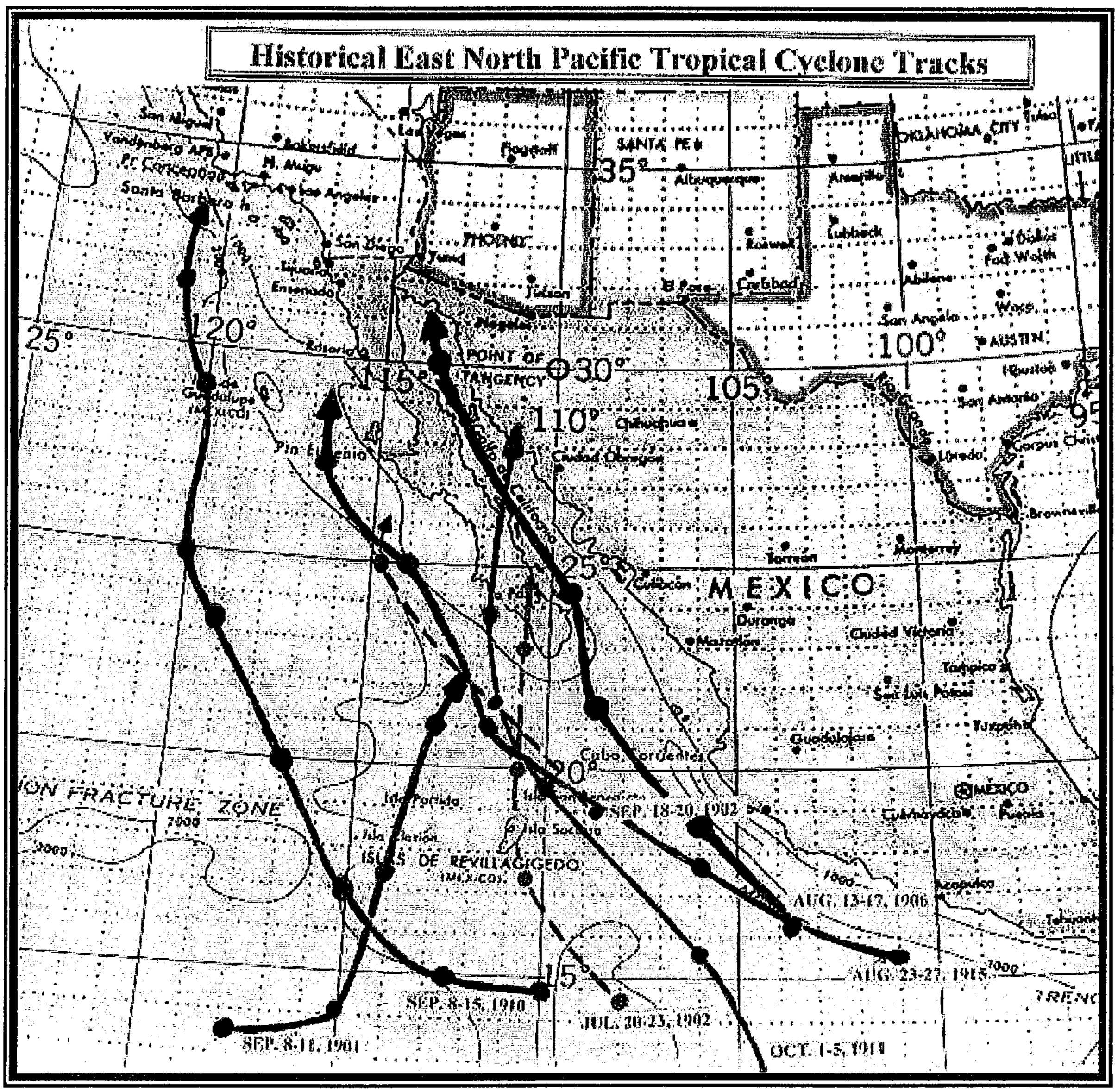
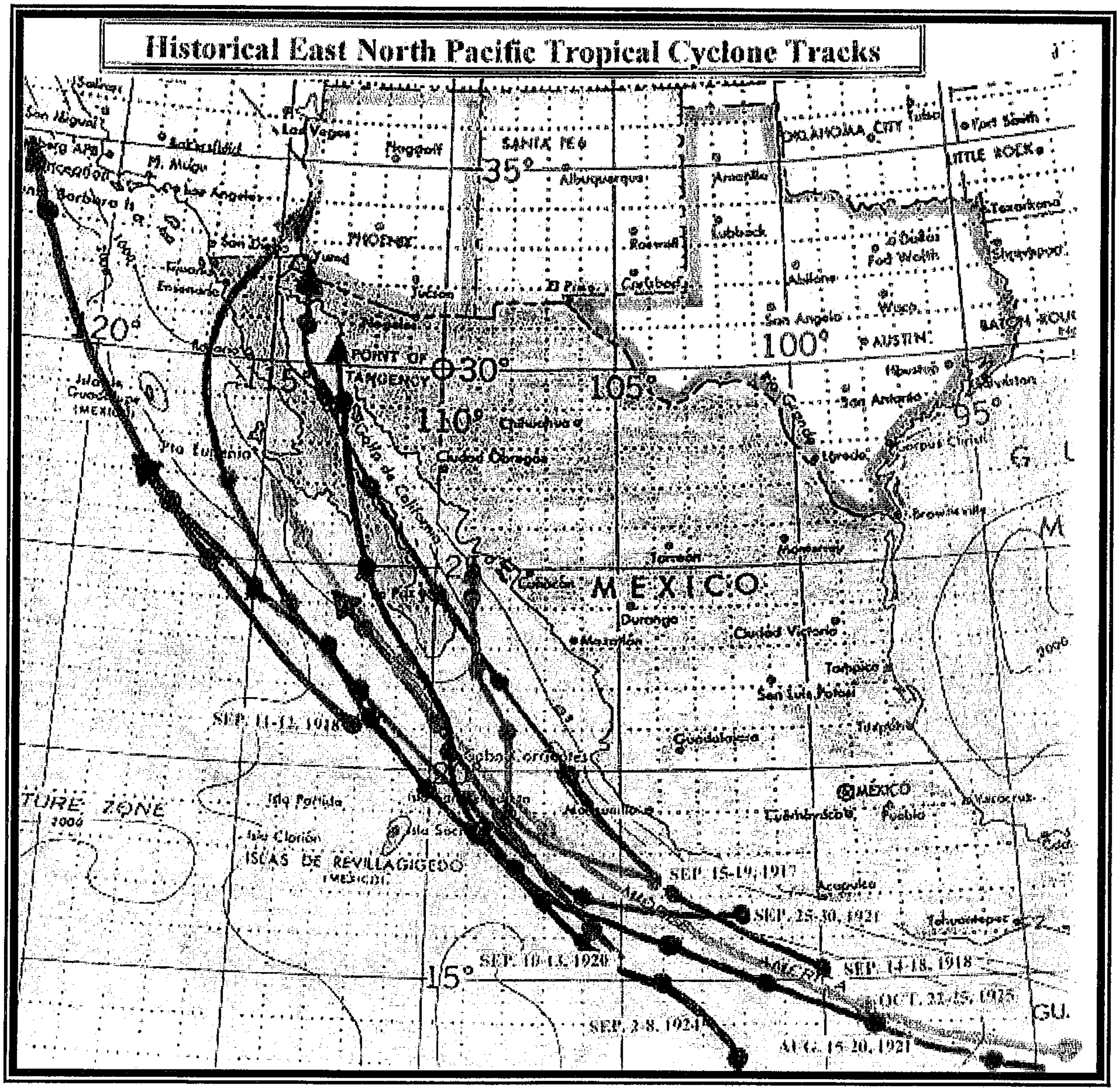
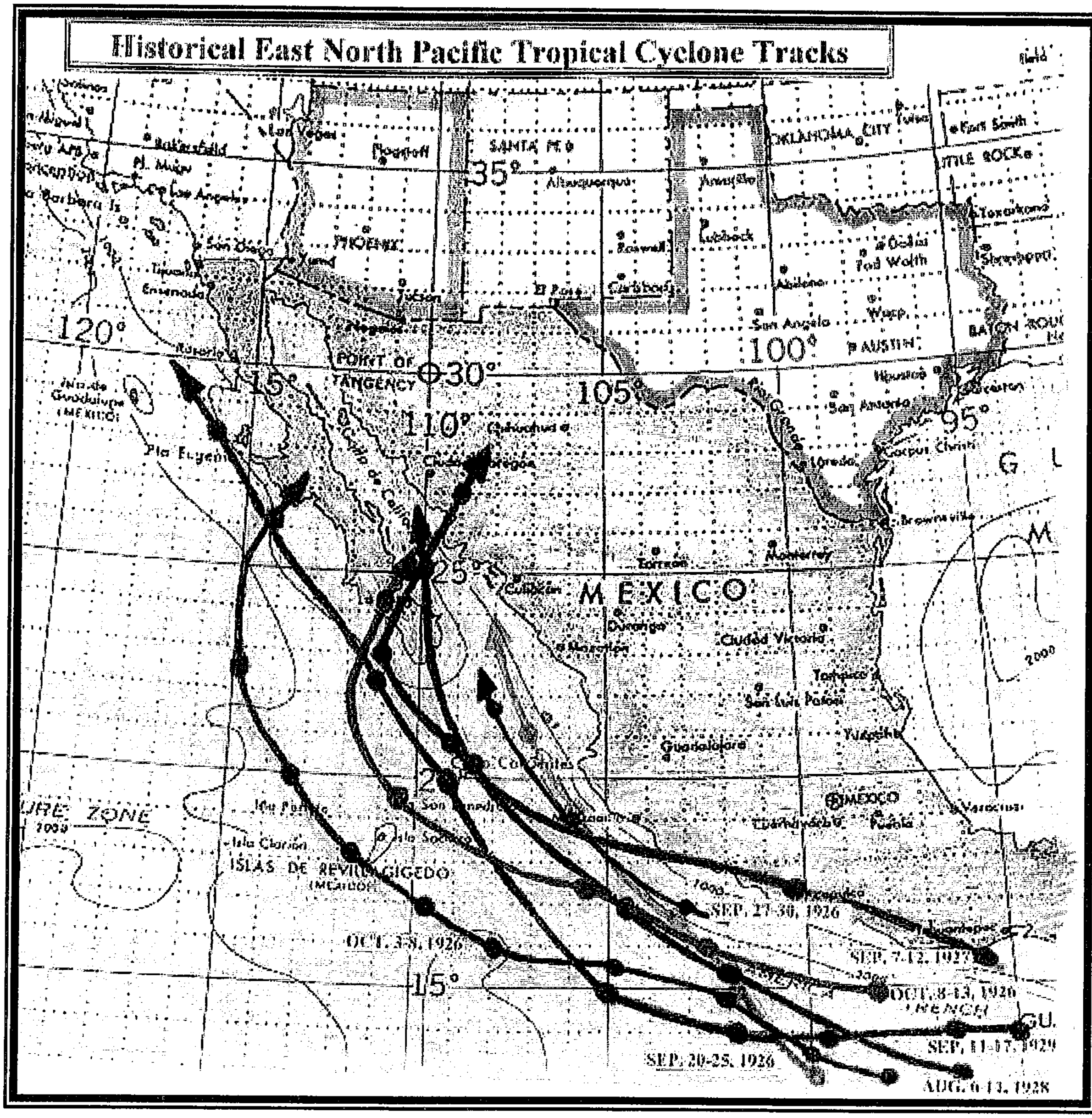


APPENDIX A
Historical tropical cyclone tracks for the East North Pacific for the period 1901 - 1915.

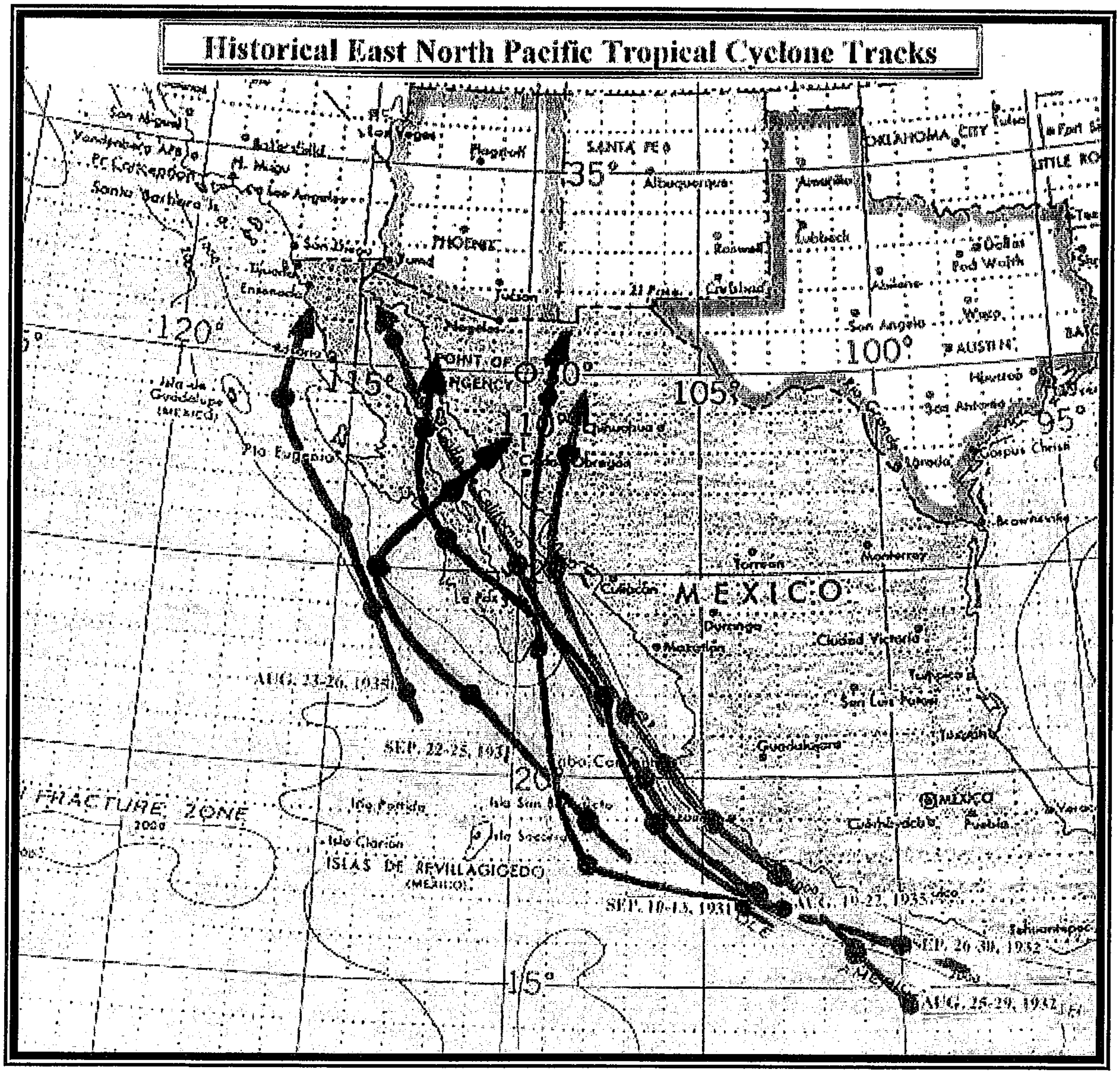


APPENDIX B

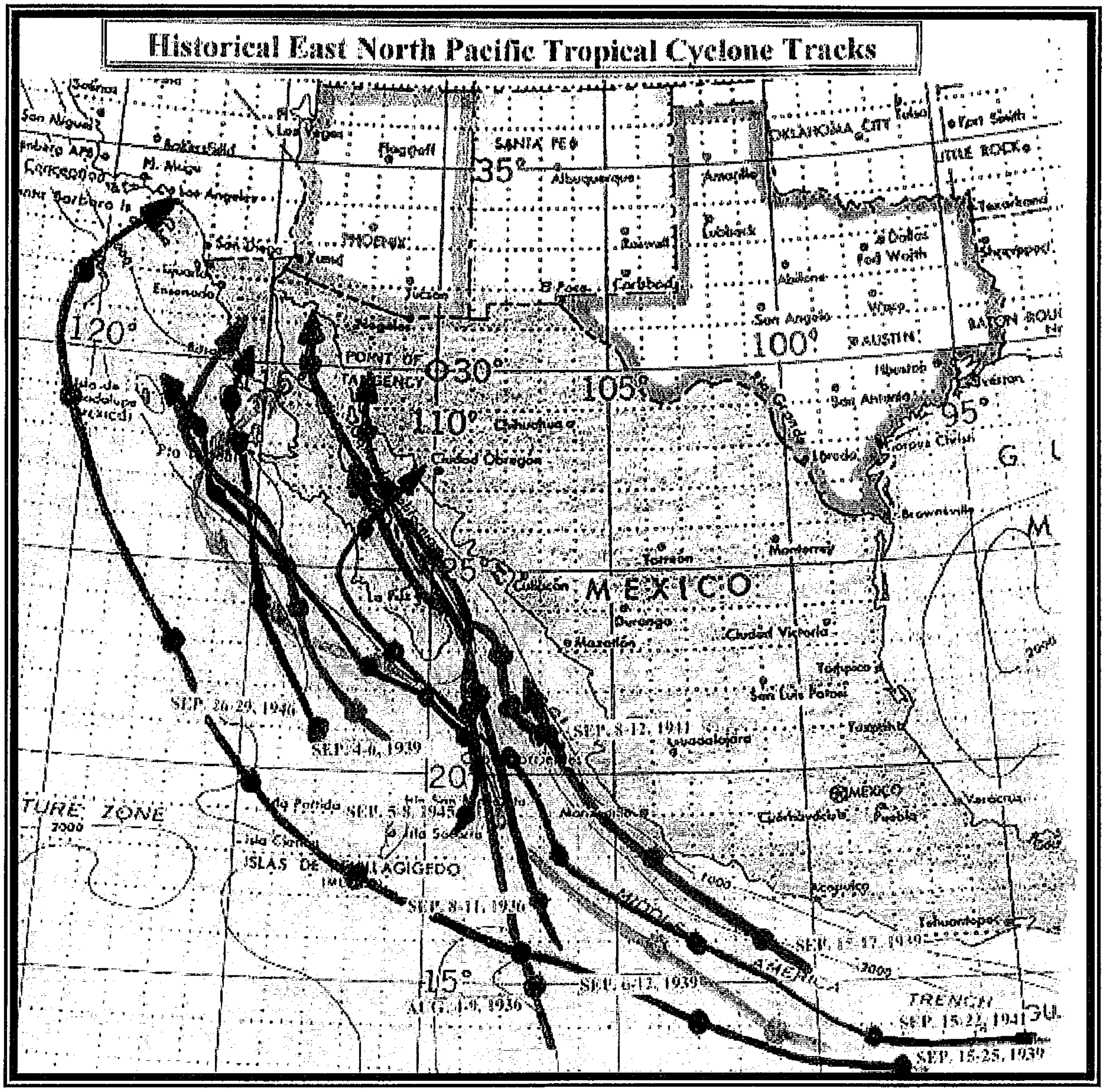
Historical tropical cyclone tracks for the East North Pacific for the period 1916 - 1925.



APPENDIX C
Historical tropical cyclone tracks for the East North Pacific for the period 1926 - 1930.

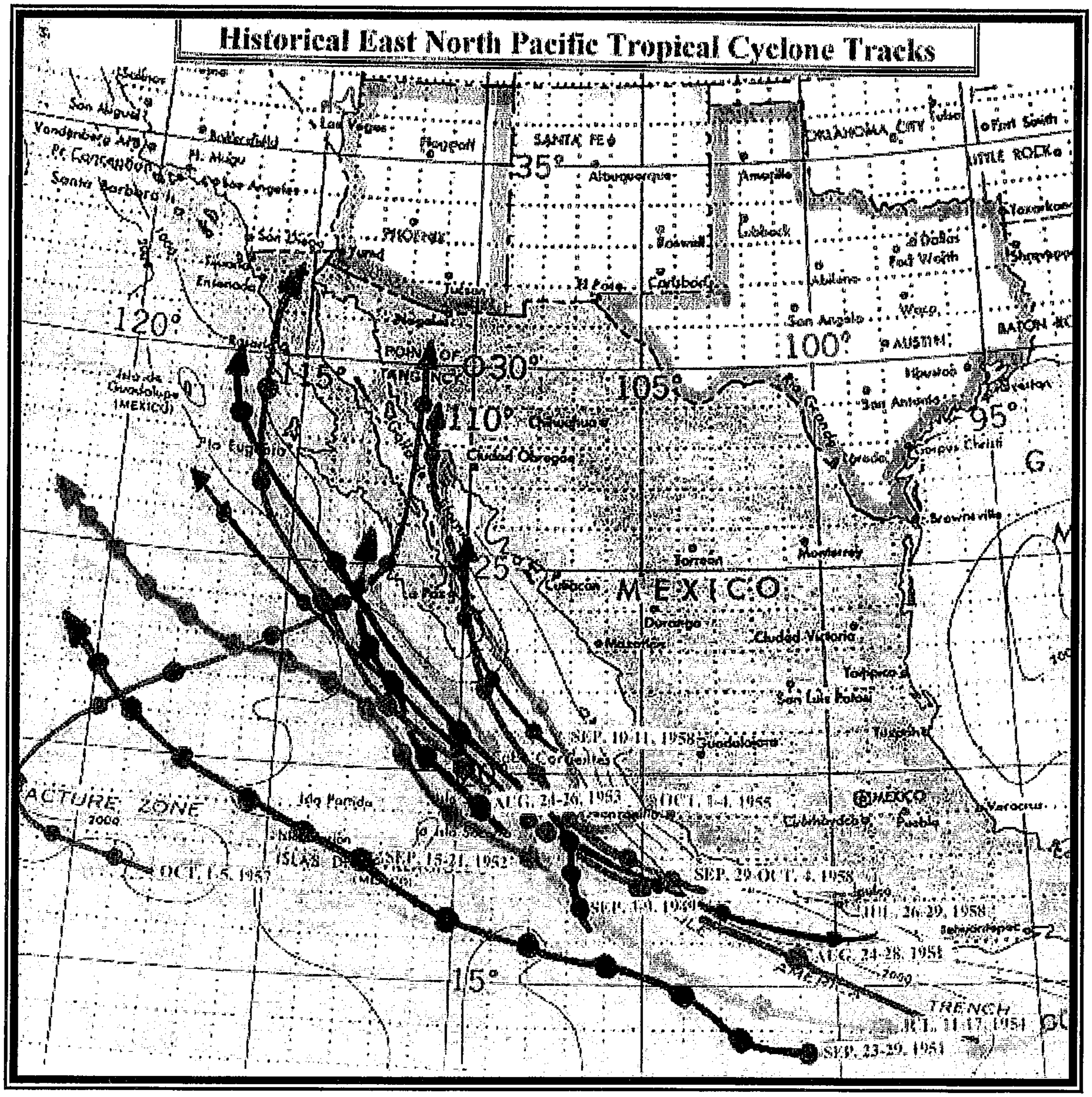


APPENDIX D
Historical tropical cyclone tracks for the East North Pacific for the period 1931 - 1935.



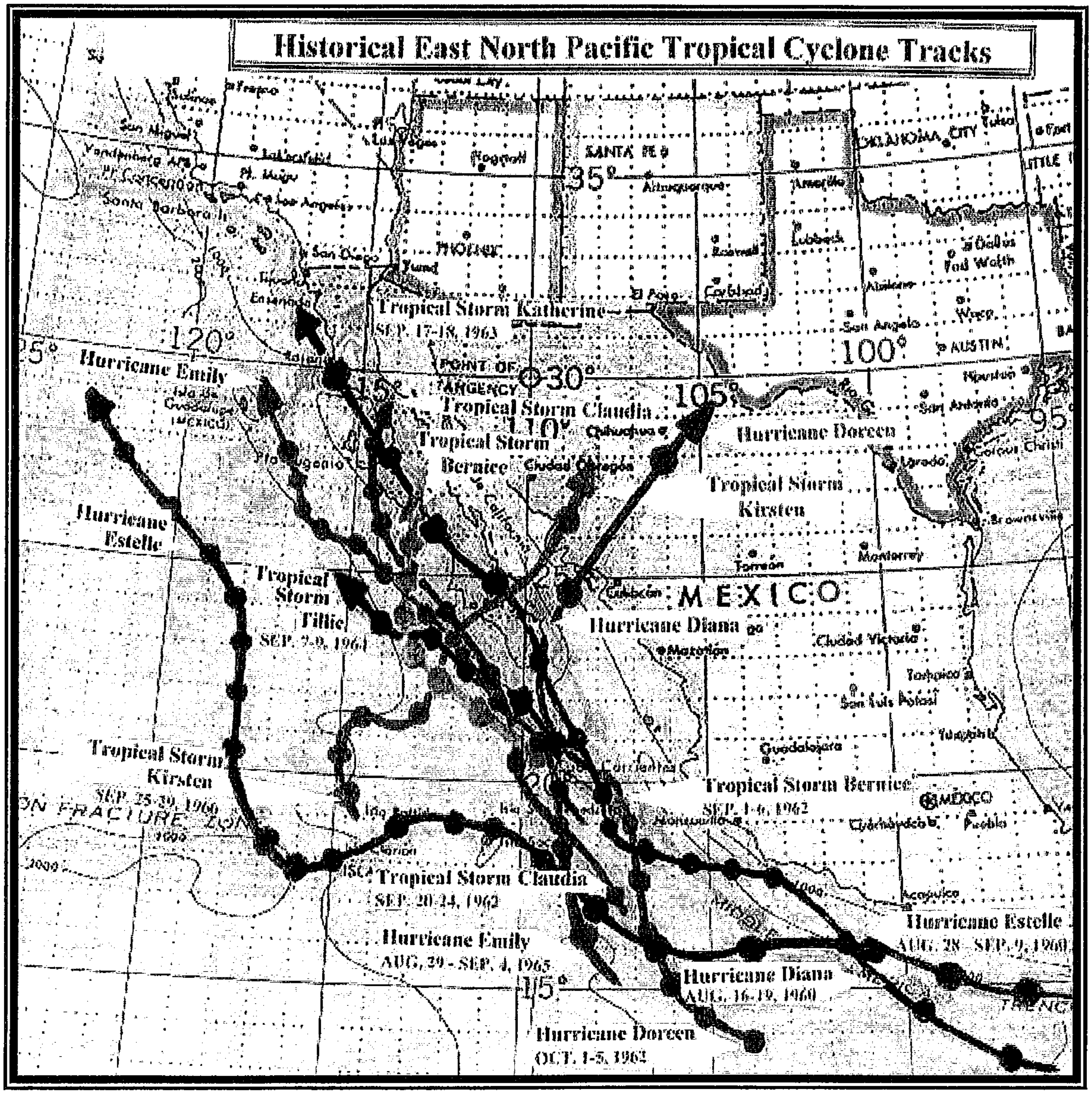
APPENDIX E

Historical tropical cyclone tracks for the East North Pacific for the period 1936 - 1946.



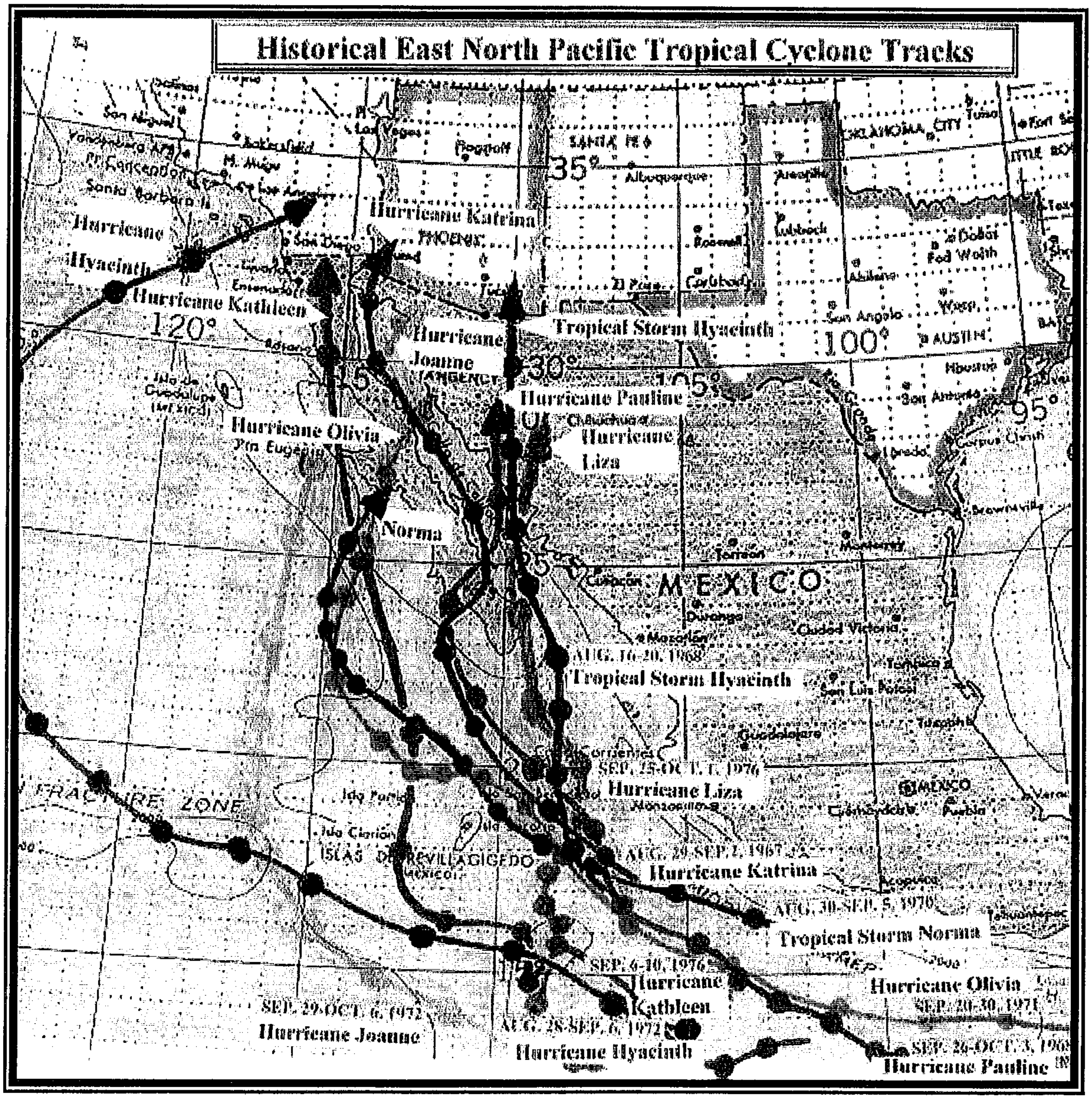
APPENDIX F

Historical tropical cyclone tracks for the East North Pacific for the period 1947 - 1959.

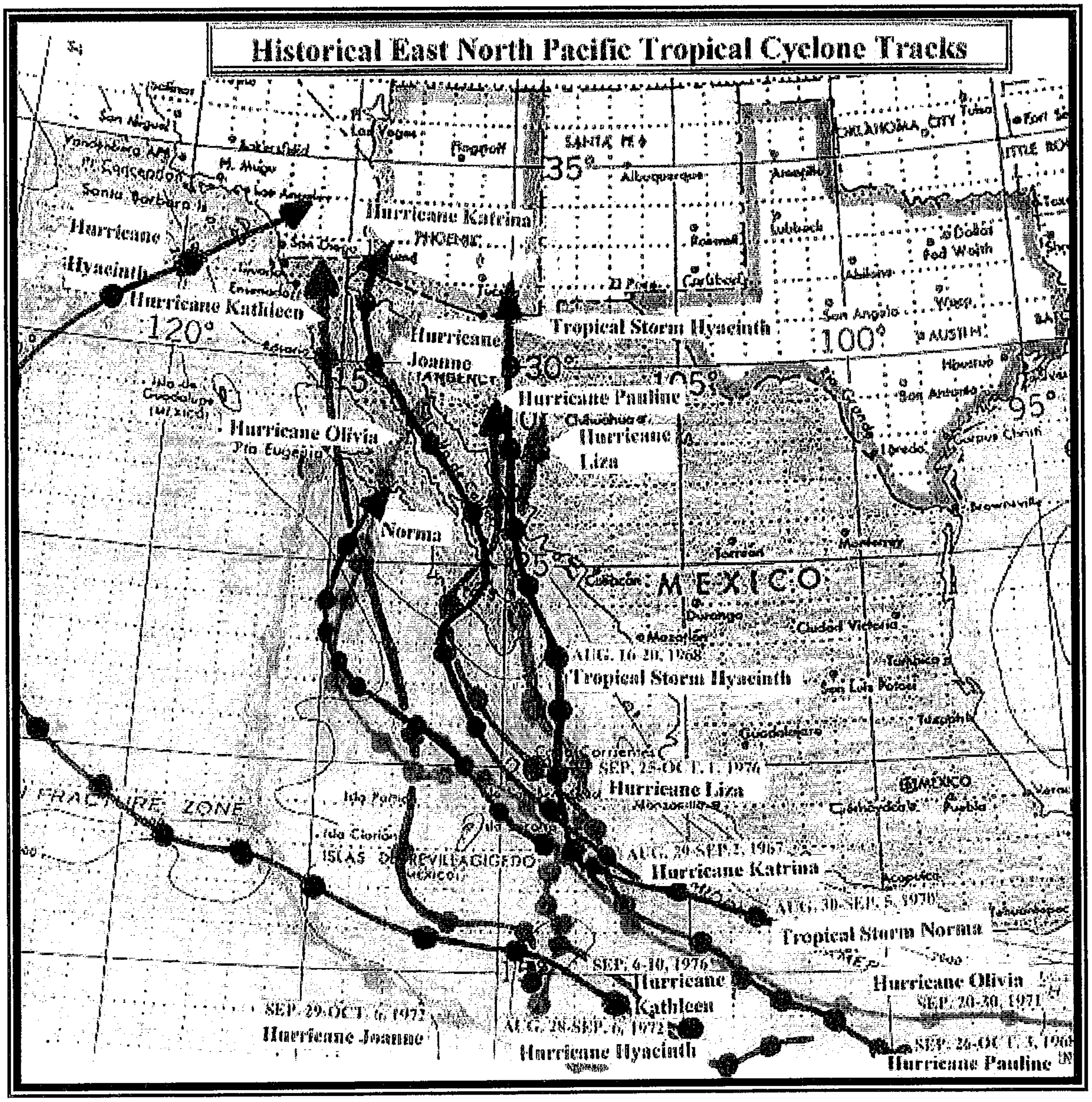


APPENDIX G

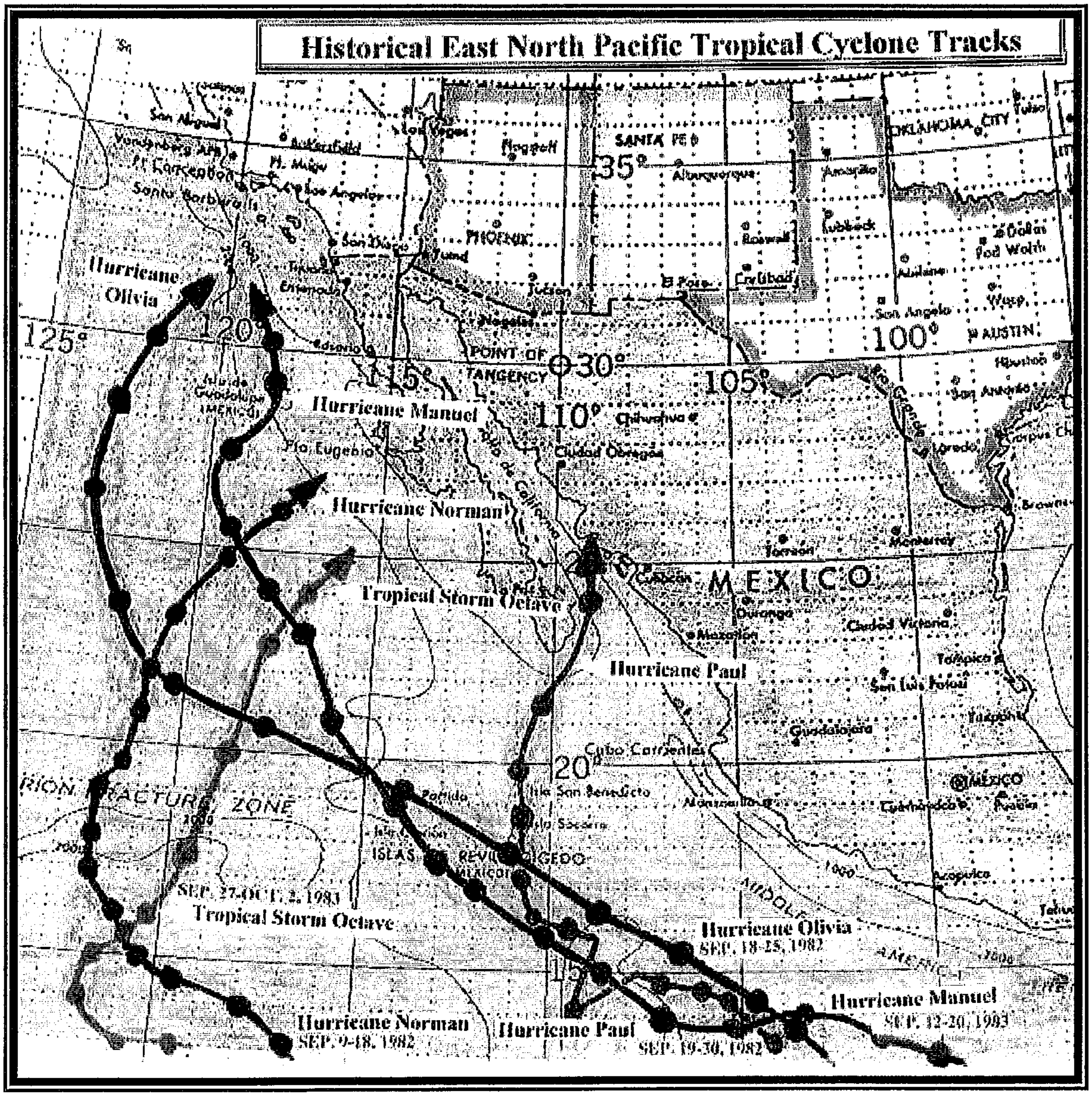
Historical tropical cyclone tracks for the East North Pacific for the period 1960 - 1966.



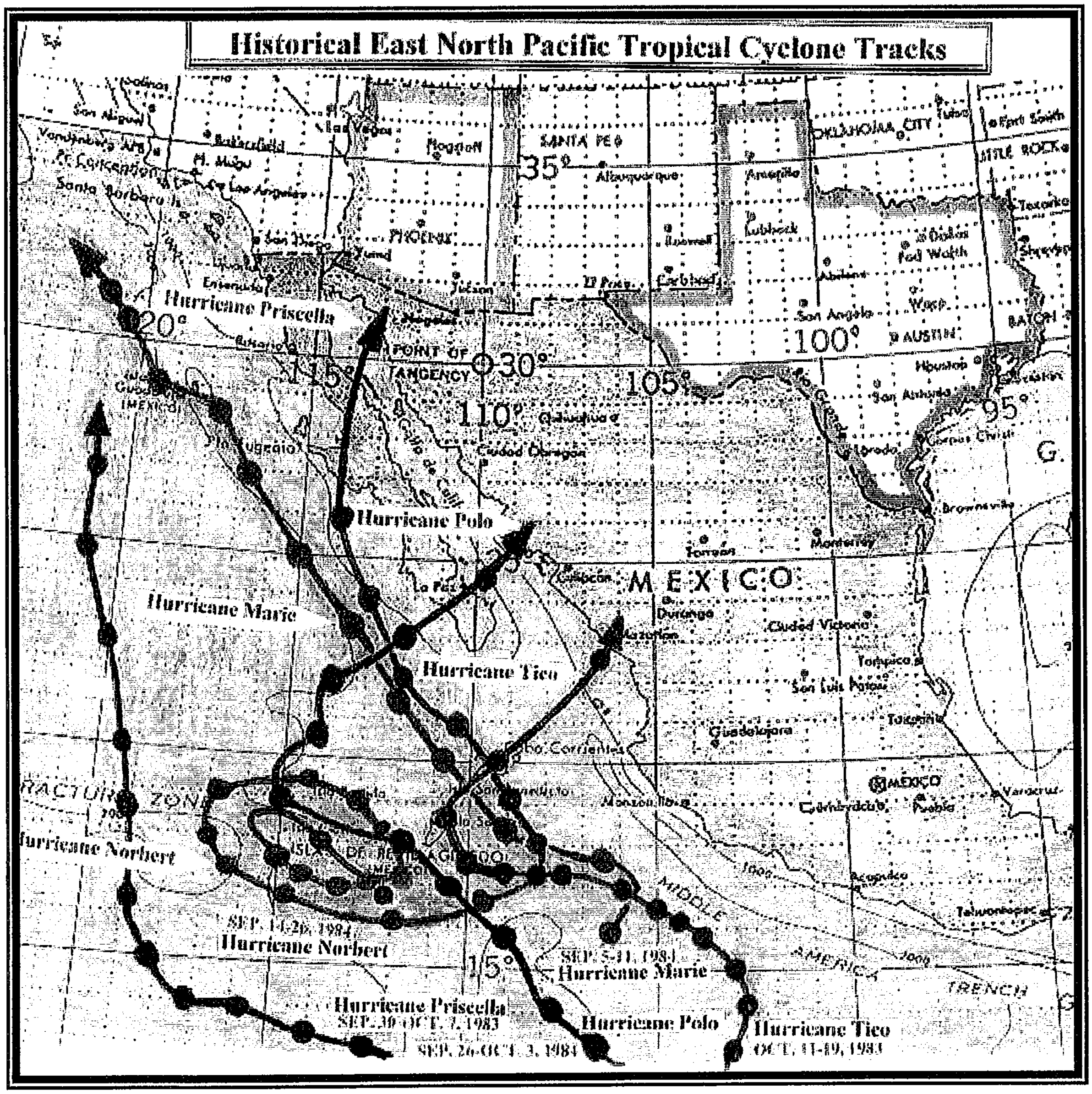
APPENDIX H
Historical tropical cyclone tracks for the East North Pacific for the period 1967 - 1976.



APPENDIX H
Historical tropical cyclone tracks for the East North Pacific for the period 1967 - 1976.

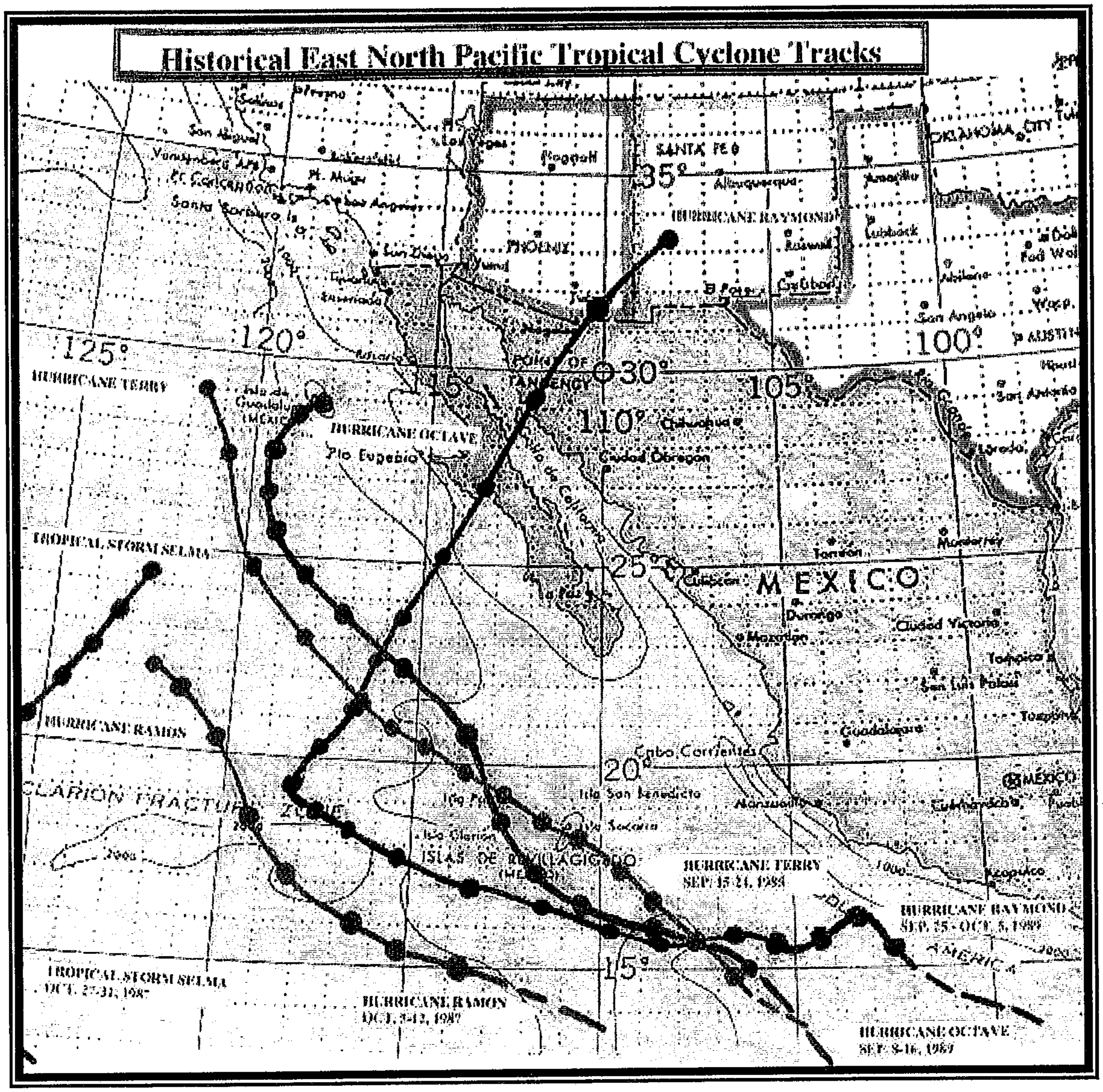


APPENDIX J
Historical tropical cyclone tracks for the East North Pacific for the period 1981 - 1983.

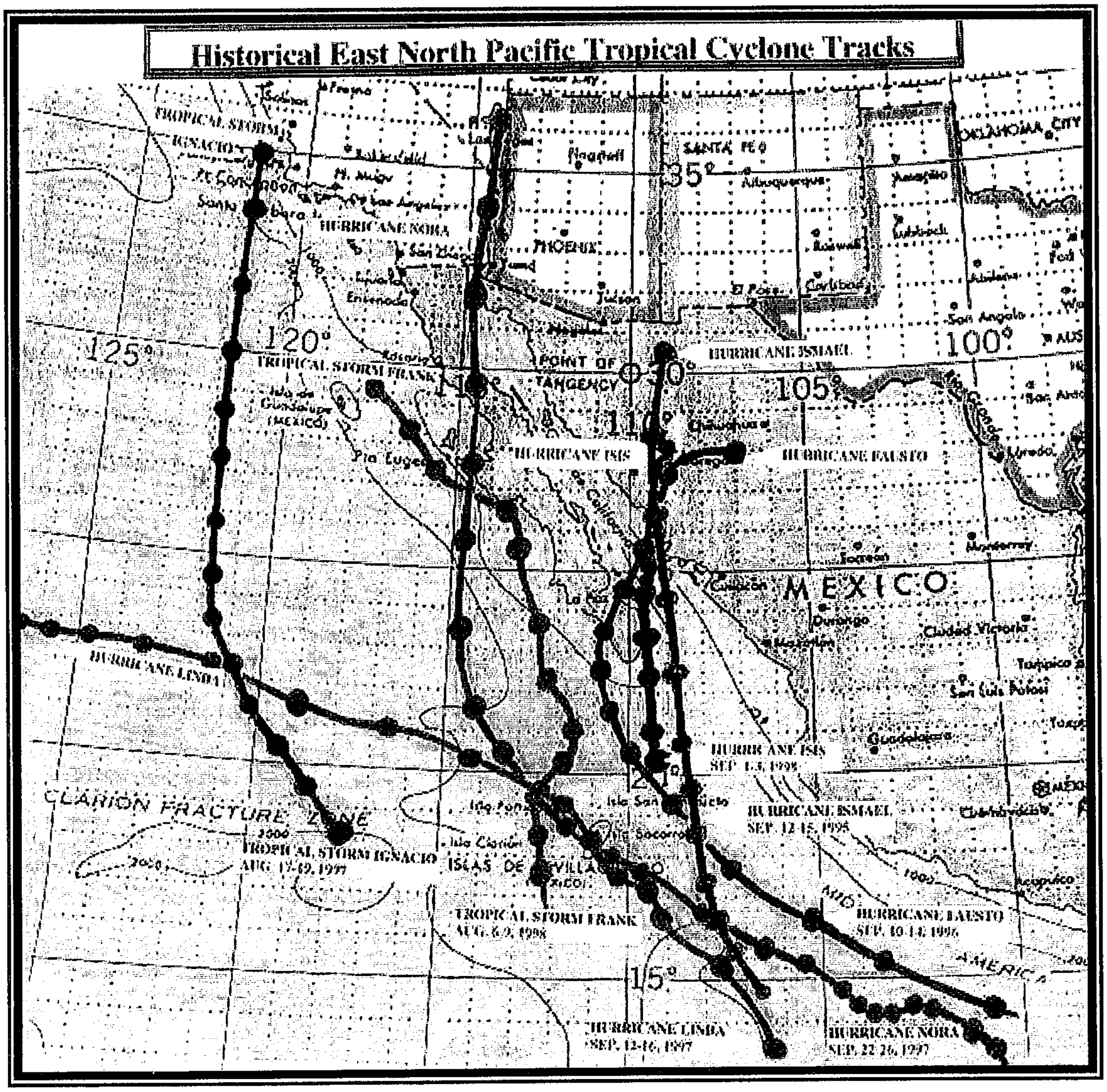


APPENDIX K

Historical tropical cyclone tracks for the East North Pacific for the period 1983 (cont.) - 1984.



APPENDIX L
Historical tropical cyclone tracks for the East North Pacific for the period 1985 - 1989.



APPENDIX N

Historical tropical cyclone tracks for the East North Pacific for the period 1995 - 1998.

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216 Creating MOS Equations for RAWS Stations Using Digital Model Data. Dennis D. Gettman December 1991. (PB92-131473/AS)

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221 Utilization of the Bulk Richardson Number, Helicity and Sounding Modification in the Assessment of the Severe Convective Storms of 3 August 1992. Eric C. Evenson, September 1993 (PB94-131943)

222 Convective and Rotational Parameters Associated with Three Tornado Episodes in Northern and Central California. John P. Monteverdi and John Quadros, September 1993 (PB94-131943)

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