Preliminary Report
Hurricane Nora
16-26 September 1997

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a. Synoptic History

Hurricane Nora formed early on the 16th of September about 250 nautical miles to the southwest of Acapulco (Table 1 and Fig. 1a). It originated in a large area of disturbed weather that had slowly become better organized while drifting west-northwestward during the previous few days. Analysis of satellite pictures indicates that this activity was likely related to a westward-moving tropical wave that crossed from Africa into the Atlantic hurricane basin on the 30th and 31st of August. The northern part of the wave was associated with the formation of Hurricane Erika in the central tropical Atlantic, while the southern part continued westward through the Caribbean Sea and northern South America, and arrived in the eastern Pacific basin on 12 September.

Nora matured in an environment of relatively light wind shear, and much of its development appears to have been related to variations in sea-surface temperature (SST). Nora formed over very warm water (29-30°C). Deep convection quickly increased and became organized in well-defined bands on the 16th, with Dvorak technique intensity estimates of T2.5 forming the basis for estimating that the system became a tropical storm at 1800 UTC on the 16th (Figs. 2 and 3). Further strengthening occurred over the following two days. The first signs of what would become a rather large and ragged eye were detected in infrared satellite pictures early on the 18th. By late that day, Nora was a hurricane with 90-kt sustained winds.

During Nora's first few days, the winds around a mid-level high over northern Mexico helped direct the tropical cyclone slowly toward the west-northwest. From midday on the 18th to early on the 20th, however, Nora nearly stalled. The hurricane weakened during that period. The height, amount, and organization of convection decreased and the eye disappeared. The maximum wind speed is estimated to have decreased to 65 knots. This weakening is presumed to have occurred in response to the hurricane's prolonged stay over waters cooled by upwelling beneath its circulation. Analyses in this part of Nora's wake show SSTs cooled by about 2°C, on average, to about 27°C.

By late on the 20th, Nora was on the move again, at 5 to 10 knots toward the west-northwest or northwest, roughly parallel to the southwest coast of Mexico. Nora then rapidly restrengthened.

The eye reappeared, initially with a diameter of 15 nautical miles, and cloud tops cooled. Nora reached its peak maximum wind speed of 115 kt near 1200 UTC on the 21st.

On the 21st through the 23rd, Nora's track converged with, and then followed, the track previously taken by Hurricane Linda (Fig. 1b). In that area, Linda had been the strongest eastern Pacific hurricane on record just a few weeks earlier and its circulation had induced lower SSTs. Nora gradually weakened over Linda's wake, with the eye temporarily broadening to a diameter of about 50 nautical miles and the eyewall becoming broken. Estimated wind speeds decreased to about 70 knots at 1800 UTC on the 23rd.

An omega-like blocking pattern developed over the western United States during the last week of September. This left a weakness in the height pattern to the north of Nora and eventually a trough with a cut-off low to the northwest of the hurricane. The track of Nora became north-northwestward and then northward on the 24th. This carried Nora over yet another SST anomaly, a large patch of waters more than 2°C above normal abutting the west coast of Baja California. Nora remained over waters of at least 26°C all the way to its landfall on the morning of the 25th at Punta Euguenia and then about 50 nautical miles south-southeast of San Fernando, Baja California. Hence, Nora had restrengthened slightly, and then weakened less quickly than most tropical cyclones in that area. It was still at hurricane strength during its landfalls.

Nora was accelerating northward at landfall, steered by the flow associated with the trough to its northwest. The center of the cyclone crossed the Baja California peninsula at 20-25 knots and traveled up the western shoreline of the Gulf of California. It crossed into the United States, near the California/Arizona border, still as a tropical storm, near 2100 UTC on the 25th. Most of the heaviest precipitation was then located to the northeast of the center.

Rapid weakening ensued and winds dropped to tropical depression strength near 0000 UTC on the 26th, when the center was located about midway between Blythe and Needles, California. The low-level center was moving toward the north-northeast as it degenerated early on the 26th. A remnant circulation aloft apparently persisted, however, and is likely to have been responsible for a period of near hurricane-force winds observed at the NWS Cedar City Doppler radar, located in the mountains of southwestern Utah at an elevation of about 10,600 feet.

The residual area of cloudiness and showers gradually became more diffuse over the following two days while moving generally northeastward, through portions of Utah, Colorado, Idaho and Wyoming.

b. Meteorological Statistics

Table 1 provides the post-storm "best track" location and intensity estimates for Nora. Figures 2 and 3 show the hurricane's estimated central pressure and maximum one-minute wind speed, respectively, versus time and the associated satellite data. Position and intensity estimates from satellite pictures were provided by the Air Force Global Weather Center (AFGWC), NOAA Tropical Analysis and Forecast Branch (TAFB) and NOAA Synoptic Analysis Branch (SAB).

Table 2 lists the observations of tropical storm force winds. Most came from ships at sea. A 39-kt 2-minute sustained wind was observed at Yuma during Nora's passage. Such observations of tropical storm force winds are a rarity in the United States for eastern Pacific tropical cyclones. The peak gust observed at Yuma was 47 kt. A gust to 45 kt occurred at Ajo, AZ.

The NWS Doppler radar at Yuma showed a 40 nautical mile wide band of hurricane force winds aloft to the east of Nora's center near the Arizona/Sonora border near noon on the 25th. These winds were observed at about 4-5,000 ft, could have extended to higher altitudes, and likely were related to the patch of near-hurricane force winds observed over the high terrain of southwestern Utah 12-18 hours later.

The Yuma radar indicated a small area with near 10 inches of rain along the northern Gulf of California coast of Baja California. In the United States, the 11.97 inches recorded at the 5700 ft level in the Harquahala Mountains in Arizona was, by far, the largest total (Table 3). More than three inches occurred in some spots in Arizona, California, Nevada, and Utah. Some of the amounts were comparable to the local yearly average rainfall.

c. Casualty and Damage Statistics

Two deaths were reported from Mexico in association with Nora. One person was electrocuted by a downed power line in Mexicali. The other fatality occurred to a diver caught in strong underwater currents created by Nora off the coast of the San Quintin Valley. In the United States, there were no deaths directly related to Nora. The California Highway Patrol attributed three or four traffic fatalities in southern California to weather.

Although Nora remained well offshore from southwestern mainland Mexico, the Associated Press reported that waves to 16 feet hit that coastline, destroying dozens of homes. It also destroyed the Pie de la Cuesta beaches of Acapulco.

About 350 to 400 people were made homeless by floodwaters in the town of Arroyo de Santa Catarina in northern Baja California. Heavy damage and flooding was reported in San Felipe, on the

northwestern shore of the Gulf of California. On the northeastern shore, at Puerto Peñasco, Nora's winds blew down trees, billboards, electric wires, taco stands, and ripped sheet-metal from homes. Waves of 10 feet were reported there.

Damage totals in the United States are incomplete at this time but media summaries of Nora included a loss to agriculture preliminarily estimated at several hundred million dollars. About a $30 to 40 million loss to lemon trees was estimated.

In Somerton, AZ, 10 miles south of Yuma, damage to mobile homes and flooding was reported. About 12,000 people lost power in Yuma.

In California, about 125,000 customers lost power in the Los Angeles area with scattered, much smaller outages elsewhere. In San Diego, El Centro, Palm Springs and Indio, street flooding was reported. Winds knocked down about 16 power poles in Seeley.

The remnant circulation aloft apparently downed and/or sheared off the tops of hundreds of large (1-2 ft diameter) trees in southwestern Utah, mainly at elevations above 10,000 feet in the area that includes the Dixie National Forest. Three residences in that region were damaged by falling trees and power was disrupted.

d. Forecast and Warning Critique

Table 4 shows the average track forecast errors of the numerical models and the NHC official forecast. On average, the best short-term track guidance was provided by the statistical track models run from the AVN and UKMET output (P91E and P9UK). The best 72-hour forecasts were made by the UKMET model. The average official forecasts were generally competitive with the best available guidance. The NHC errors were comparable to the long-term averages, except at 72 hours where they were about 20% larger than average.

The NHC intensity forecasts did not anticipate the variations in strength accompanying Nora's interaction with upwelled waters. A few forecast errors as large as 40 knots resulted. Otherwise, errors were comparable to long-term averages (which increase to about 20 kt at 72 hours).

Table 5 lists the tropical storm and hurricane watches and warnings issued by the government of Mexico. Warnings for high swells and waves were also posted for portions of the coast of Mexico.

The threat to the southwestern United States was unusual and required an unprecedented coordination between the NHC and offices in the NWS Western Region. In one instance, a conference call was held with about twelve offices (including the Salt Lake City RFC,

Western Region MSD, HPC, and Navy METOC facility in San Diego). From the NHC perspective, the coordination was smooth and effective.

Acknowledgments

Operational assistance and data for this report were provided to the NHC by NWS offices in Phoenix, Tucson, Flagstaff, Las Vegas, Salt Lake City, San Diego and Oxnard.

Table 1. Preliminary best track, Hurricane Nora, 16-26 September 1997.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
16/0600	12.7	101.7	1004	25	Tropical Depr.
1200	13.2	101.9	1003	30	" "
1800	13.6	102.1	1001	35	Tropical Storm
17/0000	13.9	102.3	1000	40	" "
0600	14.0	102.4	998	40	" "
1200	14.1	102.5	996	50	" "
1800	14.3	102.7	994	55	" "
18/0000	14.3	102.9	990	55	" "
0600	14.3	103.2	990	60	" "
1200	14.1	103.5	980	75	Hurricane
1800	14.1	103.7	970	90	" "
19/0000	14.3	103.9	972	90	" "
0600	14.4	104.0	973	85	" "
1200	14.5	104.1	974	80	" "
1800	14.6	104.2	976	80	" "
20/0000	14.8	104.5	978	70	" "
0600	15.1	104.9	982	70	" "
1200	15.4	105.5	987	65	" "
1800	15.6	106.2	985	70	" "
21/0000	15.8	106.7	979	75	" "
0600	16.1	107.3	970	95	" "
1200	16.6	108.0	950	115	" "
1800	17.2	108.9	951	110	" "
22/0000	17.7	109.7	952	110	" "
0600	18.0	110.5	953	110	" "
1200	18.5	111.2	955	110	" "
1800	18.9	111.8	957	105	" "
23/0000	19.3	112.3	961	95	" "
0600	19.8	112.9	973	90	" "
1200	20.2	113.3	983	80	" "
1800	20.7	113.7	980	70	" "
24/0000	21.5	114.1	979	75	" "

Table 1 (cont.). Preliminary best track, Hurricane Nora, 16-26 September 1997.

0600	22.3	114.5	979	75	" "
1200	23.2	114.8	979	75	" "
1800	24.2	114.8	979	75	" "
25/0000	25.8	114.8	979	75	" "
0600	27.5	114.8	981	75	" "
1200	29.5	114.8	984	65	" "
1800	31.7	114.9	990	55	Tropical Storm
26/0000	34.0	114.7	997	30	Tropical Depr.
0600	36.1	114.1	1004	25	Dissipating
25/0630	27.6	114.8	981	75	Landfall near Punta Eugenia, MX
25/1100	29.3	114.8	983	70	Landfall SSE of San Fernando, MX
21/1200	16.6	108.0	950	115	Minimum Pressure

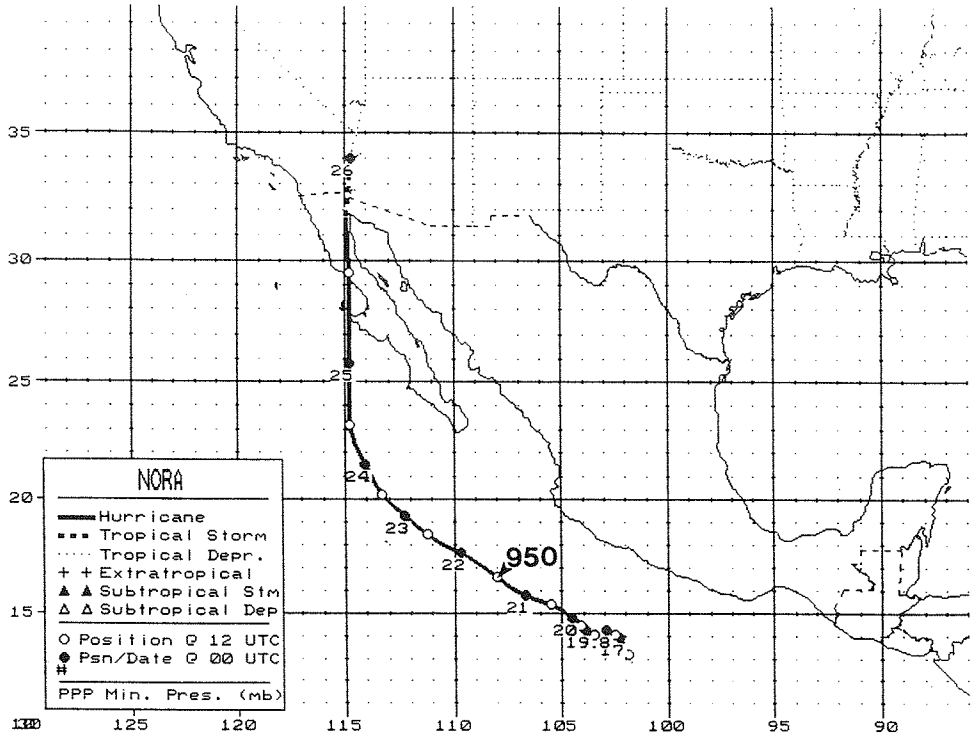

Figure 1a. Best track of Hurricane Nora, September 1997.

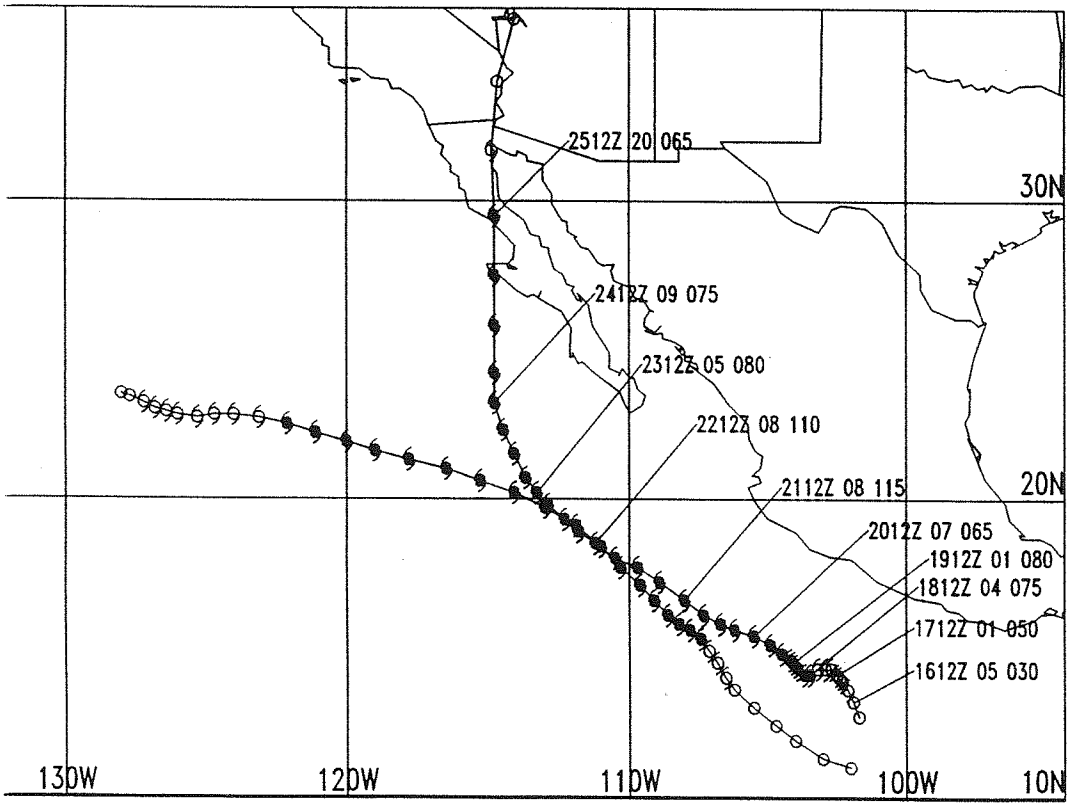

Figure 1b. Best track of Hurricane Nora, September 1997 (1200 UTC positions labelled) and best track of Hurricane Linda.

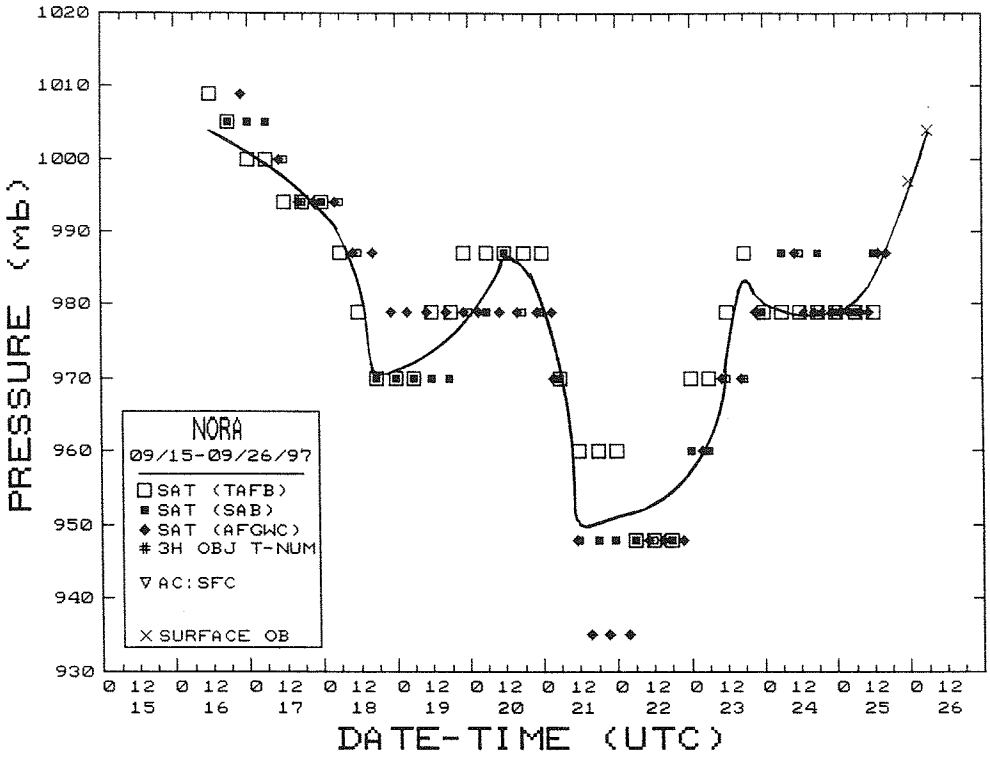

Figure 2. Best track central pressure curve for Hurricane Nora, 16-26 September 1997.

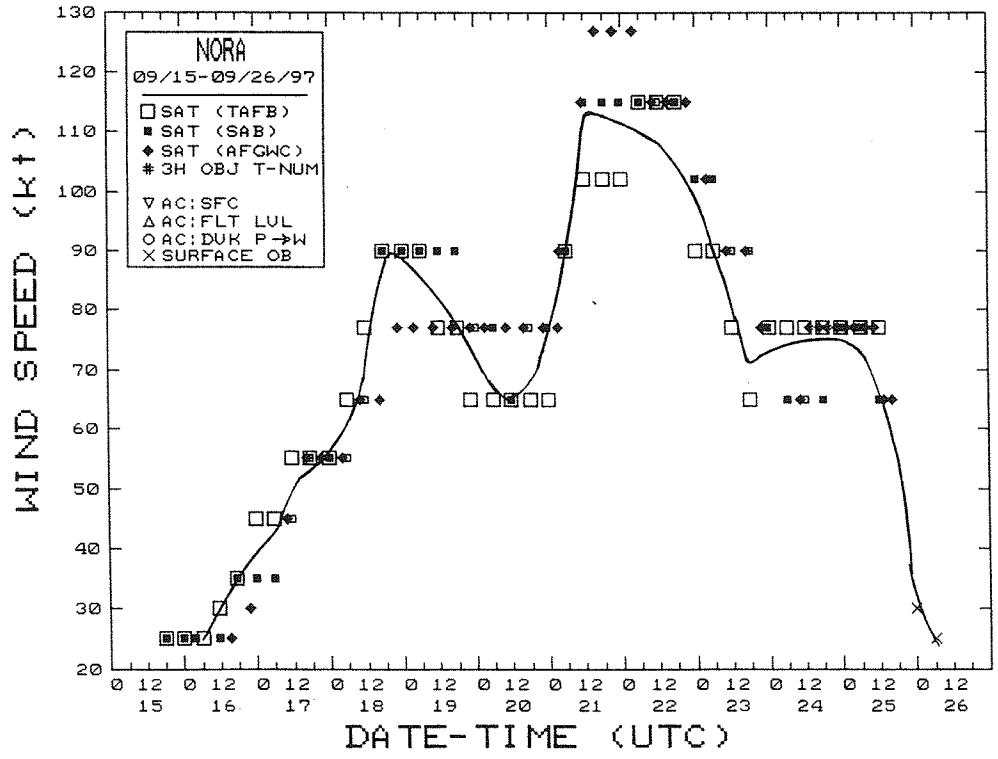

Figure 3. As in Fig. 2, except for maximum wind speed.

Table 2. Observations of 34 knots or higher sustained winds associated with Nora.

Id	Name	Date/Time (UTC)	Lat. Lon.	Wind Dir./Spd.	Pressure (mb)
3FGI5	-----	18/1800	17.0 101.8	110/44	------
C6FA6	Kenneth P. Hill	18/2100	12.5 103.9	250/40	994.0
PGRO	Pauwgracht	18/2100	16.1 99.8	140/58	1009.0
C6FA6	Kenneth P. Hill	19/0000	12.3 103.3	260/37	994.0
PGRO	Pauwgracht	19/0300	---- -----	130/35?	1009.0
PGRO	Pauwgracht	19/0600	17.0 101.5	120/37	1008.8
3ERJ8	Georgia Rainbow II	21/0000	15.7 108.6	320/48	999.0
3ERJ8	Georgia Rainbow II	21/1200	14.7 106.7	180/39	1001.5
PFSJ	Magic	21/1800	11.4 107.4	220/47	1008.5
STORM	-----	22/1200	---- -----	110/35?	1006.0
STORM	-----	22/1500	21.3 106.6	150/35	1007.5
ZCBD9	-----	23/0000	22.5 109.4	110/40	1001.7
ZCBL6	-----	23/0000	20.3 106.8	140/40	------
ZCBD9	-----	23/0600	22.0 107.8	140/40	1005.4
ZCBL6	-----	23/2100	22.1 110.9	140/35	1002.8
YJZL7	Wislanes	24/1200	23.1 111.1	140/35	1003.3
ZCBL6	-----	24/1500	25.0 113.5	120/44	998.2
ZCBL6	-----	24/1800	25.2 113.8	120/44	995.8
ZCBL6	-----	24/2100	25.3 113.8	140/48	989.0
ZCBL6	-----	25/0000	25.2 113.7	160/50	991.8
76723	Socorro Island, MX	22/0000	18.7 111.0	340/45	992.8
76401	El Medano(?), MX	24/0600	24.4 111.3	140/40?	998.5
76061	Puerto Peñasco, MX	25/1500	31.3 113.6	---/35	
76061	Puerto Peñasco, MX	25/1800	31.3 113.6	100/35	1002.7
72280 (YUM)	Yuma Arizona Marine Corps Naval Air Station ASOS	25/2106	32.7 114.6	150/39 Peak Gust 47 at 2107	994.6 at 25/2103

Table 3. Storm-total rainfall reports exceeding 3 inches (except for a few ALERT gauges in southern California), and selected additional sites with smaller totals, associated with Nora.

Reports of > 3 inches			Selected Sites	
Harquahala Mtns @5700', AZ	11.97		Idyllwild, CA	2.86
Yarnell Hill, AZ	6.26		Prescott, AZ	2.37
Harquahala Mountains, AZ	5.97		Grand Canyon Nat. Pk., AZ	2.05
Bagdad, AZ	5.75		Blythe, CA	2.03
Thumb Butte Tank, AZ	5.75		Thermal, CA	1.99
Mayer, AZ	5.06		Escondido, CA	1.84
Crown King, AZ	4.79		Mt. Wilson, CA	1.79
Mt. Laguna, CA	4.70		Palm Springs, CA	1.73
15 miles W Wickenberg, AZ	4.53		Flagstaff, AZ	1.70
Hualapai Mountain, AZ	4.50		Daggett, CA	1.55
Centennial Wash, AZ	4.21		China Lake, CA	1.49
Tiger Wash Fan, AZ	4.17		Imperial Beach, CA	1.35
Gladden, AZ	4.02		Chula Vista, CA	1.33
Upper Tiger Wash, AZ	3.82		Henderson, NV	1.27
Turtle People, AZ	3.70		Kingman Airport, AZ	1.13
Flores West, AZ	3.66		Death Valley (Furnace Ck)	1.11
Upper Morongo Creek, CA	3.61		Organ Pipe Nat. Mon., AZ	1.11
Yuma Marine Corps NAS	3.59		Lake Havasu, AZ	1.00
Upper Tahquitz Creek, CA	3.58		Palmdale, CA	0.97
Wilhoit, AZ	3.54		Imperial, CA	0.96
Horsethief Basin, AZ	3.39		Twenty-Nine Palms, CA	0.96
Lava Point, UT	3.30		San Diego, CA	0.80
Wickenberg, AZ	3.25		San Gabriel, CA	0.78
Mt. Charleston, NV	3.25		Las Vegas (NWS office)	0.77
Mt. Union, Az	3.23		Pasadena, CA	0.70
Hartman Wash, AZ	3.19		Laughlin, NV	0.60
Sols Tank, AZ	3.15		Bullhead City, NV	0.60
Mid-Martinez Creek, AZ	3.11		LA Civic Center, CA	0.45
Hassy @ Box Canyon, AZ	3.07		Long Beach, CA	0.44
Banning Bench, CA	3.07		Tonopah, NV	0.34
Raywood Flat, CA	3.07		Los Angeles (LAX), CA	0.26
			Bishop, CA	0.13
			Phoenix, AZ	0.03

Table 4

Preliminary forecast evaluation of Hurricane Nora
Heterogeneous sample

(Errors in nautical miles for tropical storm
and hurricane stages with number
of forecasts in parenthesis)

Technique	Period (hours)				
	12	24	36	48	72
CLIP	33 (35)	65 (33)	99 (31)	141 (29)	218 (25)
GFDI	44 (29)	82 (27)	117 (25)	157 (24)	253 (20)
GFDL*	52 (16)	84 (15)	119 (14)	155 (13)	235 (11)
LBAR	33 (35)	68 (33)	107 (31)	155 (29)	263 (25)
MRFO*	42 (9)	103 (8)	167 (8)	205 (7)	293 (6)
AVNO*	40 (16)	89 (15)	147 (14)	202 (13)	269 (11)
AVNI	57 (28)	118 (26)	170 (24)	210 (23)	290 (19)
BAMD	34 (34)	72 (32)	112 (30)	157 (28)	257 (24)
BAMM	47 (34)	93 (32)	140 (30)	192 (28)	283 (24)
BAMS	58 (34)	114 (32)	169 (30)	221 (28)	298 (24)
P91E	28 (34)	54 (32)	83 (30)	127 (28)	231 (24)
NGPS*	82 (20)	129 (18)	169 (18)	198 (18)	273 (15)
NGPI	57 (21)	100 (20)	140 (20)	180 (20)	297 (15)
UKM*	38 (16)	59 (16)	90 (15)	105 (14)	180 (12)
UKMI	41 (34)	75 (33)	90 (31)	118 (29)	193 (25)
P9UK	28 (15)	55 (14)	82 (13)	113 (12)	213 (10)
NHC OFFICIAL	26 (35)	57 (33)	97 (31)	144 (29)	233 (25)
NHC OFFICIAL (1988-1996 9-year average)	39 (2288)	71 (2058)	105 (1822)	138 (1607)	194 (1228)

* Output not available until after the NHC forecast is issued.

Table 5

Tropical Cyclone watch and warning summary, Hurricane Nora

Date/Time (UTC)	Action	Location
16/2100	Hurricane Watch issued	Lazaro Cardenas to Cabo Corrientes, Mexico
17/0000	Tropical Storm Warning issued	Lazaro Cardenas to Punta Maldonado, Mexico
17/2100	Tropical Storm Warning discontinued	Lazaro Cardenas to Punta Maldonado, Mexico
18/2100	Hurricane Watch discontinued	Lazaro Cardenas to Cabo Corrientes, Mexico
21/0900	Hurricane Watch issued	Revillagigedo Islands, Mexico
21/1500	Hurricane Warning issued--replaced Hurricane Watch	Revillagigedo Islands, Mexico
23/0300	Tropical Storm Warning issued	Baja California south of 25°N latitude
23/0300	Hurricane Watch issued	Baja California from north of 25°N to Punta Eugenia
23/2100	Tropical Storm Warning extended	Baja California from Punta Eugenia southward
23/2100	Hurricane Warning discontinued	Revillagigedo Islands, Mexico
24/0300	Hurricane Watch extended	Baja California from latitude 25°N to Punta San Carlos
24/1200	Hurricane Warning revised	Baja California Pacific coast from Bahia Ballenas to Punta Santo Tomas; Baja California Gulf of California Coast northward from Santa Rosalia

Table 5 (continued)

24/1200	Tropical Storm Warning revised	Baja California Pacific coast from Bahia Ballenas southward to latitude 24°N
24/1200	Hurricane Watch revised	Mainland Mexico northward from Bahia Kino
24/1200	Tropical Storm Watch issued	Baja California from Punta Santo Tomas to Tijuana
25/0300	Tropical Storm Warning issued	Mainland Mexico northward from Bahia Kino
25/1200	Tropical Storm Warning discontinued	Baja California southward of line from Bahia Ballenas to Santa Rosalia
25/1500	Hurricane Watch, Hurricane Warning and Tropical Storm Watch discontinued	All areas
25/1200 1500 CMC	Tropical Storm Warning revised	Gulf of California coast north of 30°N latitude
25/2100	Tropical Storm Warning discontinued	Gulf of California coast north of 30°N latitude