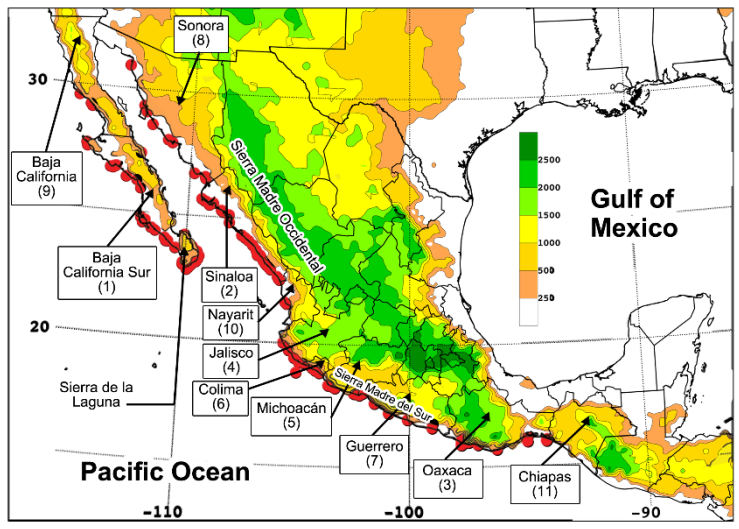
Characteristics of Tropical Cyclones Making Landfall on the Pacific Coast of Mexico: 1970-2014

Luis M. Farfán, CICESE, Mexico
Eric J. Alfaro, University of Costa Rica
Tereza Cavazos, CICESE, Mexico

Introduction

Mexico has terrain features that determine the spatial distribution of air temperature, low-level winds, and precipitation. During the warm season, low to mid-level easterly flow and tropical cyclones (TCs) play a significant role among the weather systems that originate from the western Atlantic or the eastern Pacific basins to bring significant moisture and convective activity. While most TCs develop over open ocean some of them move close to the continent to provide periods of strong winds and heavy rainfall. Eventually, their presence over land may cause property damage as well as loss of human lives. In this study, the best-track dataset compiled by the United States National Hurricane Center (NHC, http://www.nhc.noaa.gov), a disaster database (EM-DAT, http://www.emdat.be), and reports from meteorological stations are used to identify the impact from landfalling TCs.

The Sierra Madre Occidental and Sierra Madre del Sur are the most relevant terrain features. The landfall distribution of TCs that moved onshore through the Pacific coastline from 1970-2010. The highest landfall frequencies are in 1) Baja California Sur, 2) Sinaloa and 3) Oaxaca. Guerrero is ranked in seventh place.



Topography of Mexico with terrain elevations (m) shaded. Red dots indicate the location of tropical cyclone landfall sites from the eastern Pacific basin.

We ranked 31 TC-related disasters by using the number of affected people and the top 10 events were chosen for further analysis. The right-side list corresponds to TCs resulting in counts from 20,000 (Paul 2006) to more than 800,000 (Pauline 1997). In total, more than 1.5 million people were affected and over 1,300 killed.

Ten most damaging tropical cyclones making landfall in western Mexico, 1970-2010

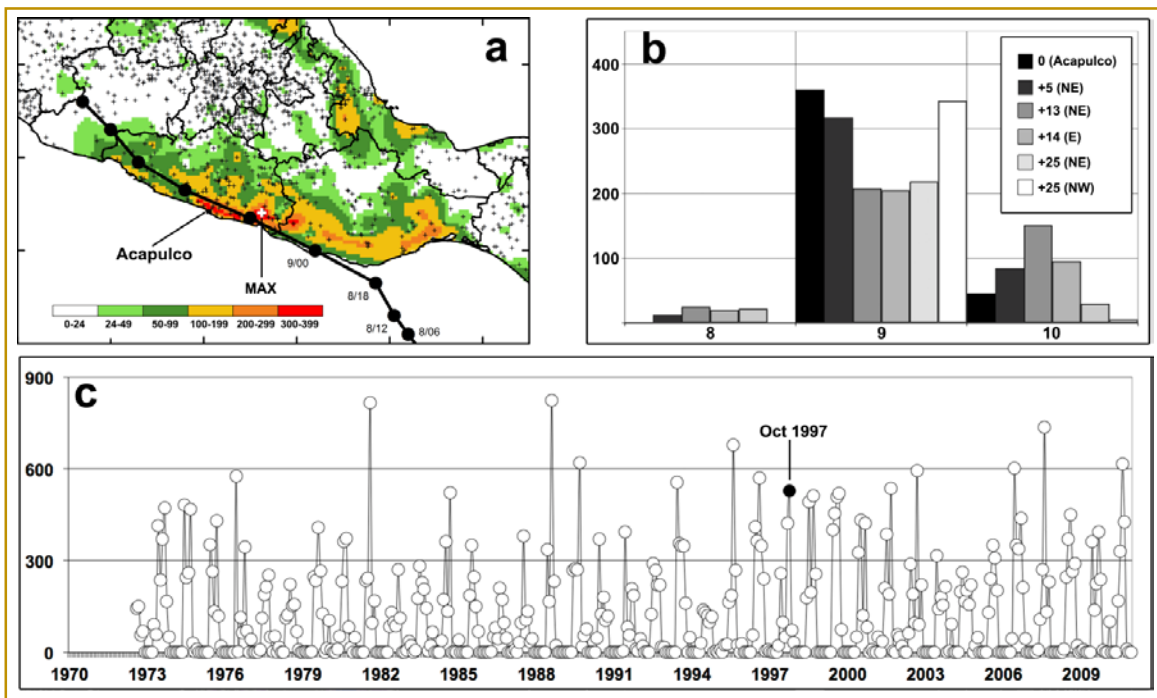
Rank	Year	TC name	Landfall intensity	Landfall date	Inhabitants affected	Inhabitants killed	ENSO phase
1	1997	Pauline	H2	Oct 8	800,200	230	EN*
2	1976	Liza	H3	Oct 1	276,400	600	EN
3	2006	Lane	H3	Sep 16	240,700	4	EN
4	2009	Jimena	H2	Sep 2	72,000	4	EN
5	1982	Paul	H2	Sep 30	50,000	225	EN*
6	1995	Ismael	H1	Sep 15	40,000	105	LN
7	1993	Calvin	H2	Jul 7	34,000	30	N
8	1993	Lidia	H2	Sep 13	30,000	1	N
9	1983	Tico	H3	Oct 19	25,000	135	N
10	2006	Paul	TD	Oct 26	20,000	4	EN
				Total	1,588,300	1,338	

TD= tropical depression, EN= El Niño, LN= La Niña, N= Neutral, *=relatively strong EN.

Main results from 1970-2010

- Because of the population density and the human development index, upon TC landfall, there are major differences between impacts from tracks over southern (Oaxaca or Guerrero) versus those moving in northwestern (in particular, the Baja California peninsula) Mexico.
- Baja California Sur is the state that received most of the long-term impacts due to heavy rainfall. Tropical cyclone Liza, in September of 1976, was the worst landfall event which caused 600 deaths in a single community.
- Knowledge of TC motion, wind intensity, and total rainfall accumulations are useful parameters that go along with the occurrence of property damage and loss of lives. However, our results suggest that there is a lack of a well-defined relationship between TC intensity at landfall and population impact.
- The majority of the top 10 TC-related disasters occurred during El Niño events, followed by neutral conditions. Considering top TC-related extreme rainfall events, El Niño and neutral conditions are more favorable for extreme events inducing to disasters than La Niña as also suggested by Martinez-Sanchez and Cavazos (2014).
- For more information: Farfán, L.M., E.J. Alfaro and T. Cavazos, 2013: Characteristics of tropical cyclones making landfall on the Pacific coast of Mexico: 1970-2010. *Atmósfera*, **26**(2), 163-182.

Next, there is a brief description of some case studies with strong impact in Mexico from the 1970-2010 period and from the most recent seasons.



Rainfall accumulations (a, in mm) during the period October 8-10 1997 and Pauline's best-track positions. The location of the maximum amount (MAX) is provided and plus signs are the available stations from Servicio Meteorológico Nacional.

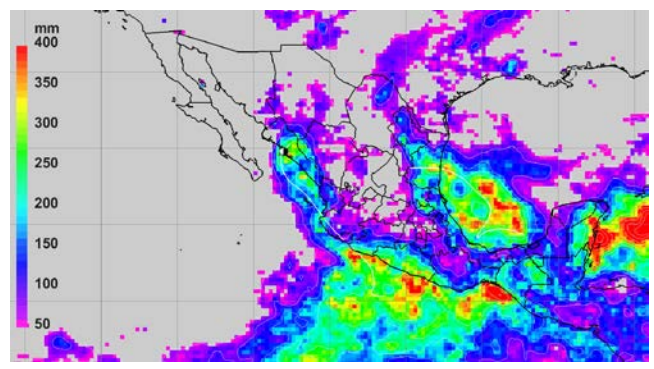
Pauline (October 1997)

Late in the season, this TC affected inhabitants in Oaxaca and Guerrero; this is considered the worst TC-related disaster experienced in the entire west coast of Mexico since 1951.

A representation of three-day rainfall accumulations from Pauline, based on the standard rain-gauge network, shown in Figure a. Accumulations reveal a distinct area around the TC track and north of the coast, in the Sierra Madre del Sur. Heavy precipitation depicts a pattern consistent with the large area of deep convection from geostationary satellite (not shown). The maximum came from a site located 25 km away from the coastline, in the eastern Guerrero foothills, and a couple of additional stations with 300-400 mm accumulations are located around Acapulco. Inspection of daily records reveals that up to 360 mm were collected on October 9 (Fig. b). Stations, within 25 km from Acapulco, reported totals between 200-345 mm and some of them resulted in new records of daily and monthly rainfall since 1972. Within the impact area, Guerrero had 27 out of the 160 available stations setting new records of daily rainfall, while only 17 (out of 105) stations set new records in Oaxaca and none in Michoacán. To provide a long-term perspective, Figure c shows a time series of Acapulco's monthly accumulations.

Manuel (September 2013)

According to EM-DAT, the TC was associated with 105,000 affected people and 169 killed. This was, mainly, due to heavy rainfall, flash flooding and mudslides over several states in southern Mexico and a secondary landfall in southern Sinaloa. Manuel made a first landfall as tropical storm, experienced slow motion and caused isolated maxima above 500 mm. One station in the Guerrero foothills recorded 315 mm during a single 24-hour period.



NASA's TRMM rainfall accumulations (mm) for September 12-20 2013. White (thin) lines represent NHC best tracks for tropical cyclones off western Mexico and in the Gulf of Mexico. Manuel made landfall in the state of Colima while Ingrid crossed the Tamaulipas coast within the next 24 hours.

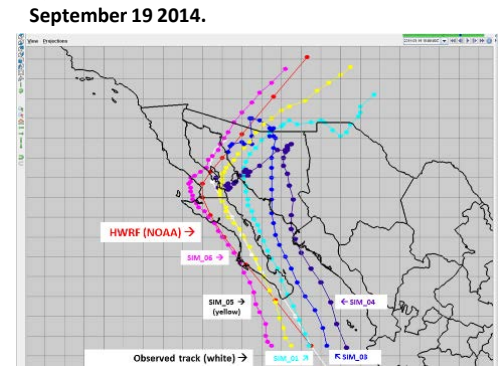
While Manuel developed off the Pacific coast, hurricane Ingrid was also active in the southwestern Gulf of Mexico (Cavazos 2015). It is likely that the combination of these hurricanes became a unique situation that provided moist flow and heavy rainfall, especially in the mountainous locations of central and southern Mexico. According to the NHC, Manuel was the first eastern Pacific TC to make landfall in the mainland, to redevelop over water in the southern Gulf of California, and go on to become a (category-one) hurricane, since their records began in 1949.

Odile (September 2014)

At landfall, since 1970, Odile became the strongest hurricane in Baja California Sur with maximum winds just above 200 km/h. This was 5 km/h below the category-4 lower margin. The impact included severe damage to the infrastructure over the Los Cabos area and, for several days, limited utilities for the population in the whole state. The maximum rainfall accumulation (533 mm) and single day (303 mm) were from a site 30 km east of the landfall site. The disaster database claims that there were 75,000 affected and 6 deaths.

An interesting aspect is related to predictions issued 24-72 hours prior to landfall. The NHC's official forecasts showed some deficiencies to provide accurate tracks. To identify the sources to this problem, we perform research that involves the operational guidance, the analysis of forecast errors, and the application of the HWRF model at CICESE's computing facility.

Damaged structures due to strong winds in an agricultural area (Miraflores) in Los Cabos, September 19 2014.



HWRF model tracks from simulations with different initial positions (longitude) associated to Odile's circulation center.