# The Contribution of Eastern North Pacific Tropical Cyclones to the Rainfall Climatology of the Southwest United States

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## Introduction

The precipitation over the southwest United States (US) rapidly increases in late June, peaks in mid-August and slowly wanes through September in association with the North American Monsoon (NAM), which brings 40-60% of the annual precipitation to the region.

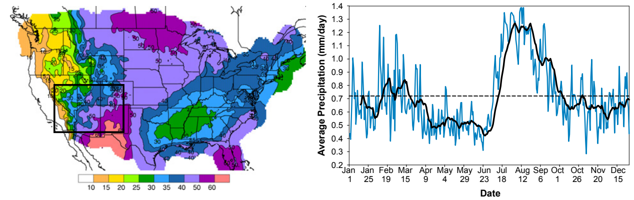



Figure 1. Left, average (1958-2003) percentage of the yearly precipitation that fell between June 16th and October 15th (defined as the warm season). The black box outlines the area 31°-40° N,104°-118° W, defined as the southwest US. Right, time series of the average (1958-2003) daily precipitation (blue curve) in the southwest US. The black curve is the 15 day running mean and the black dashed line is the daily average.

Tropical easterly waves and eastern Pacific tropical cyclones (TCs) have been found to initiate surges of moisture up the Gulf of California and into the southwest US, significantly modulating the amount of convective activity and precipitation in the region (Hales 1972; Fuller and Stensrud 2000; Higgins and Shi 2005).

Do eastern Pacific TCs ever directly impact the southwest US? Englehart and Douglas (2001) examined the influence of eastern Pacific TCs on western Mexico and found an average of 3-4 TCs impact the area every summer, accounting for ~30% of the summer rainfall. No such study has been done for the southwest US.

## Data and Methodology

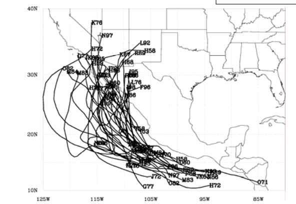
- Latitude, longitude and intensity, all eastern Pacific TCs, 16 June - 15 October 1958-2003; NHC best track
- Daily total precipitation (12 UTC – 12 UTC); NCEP/CPC Unified Precipitation Dataset (UPD)
- Dynamic and thermodynamic fields; six-hourly ERA40 analyses

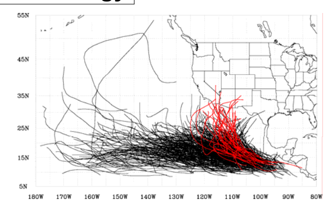
Maps of UPD rainfall were plotted for each TC from the day before it crossed 25° N for 10 days. The rainfall maps, NHC best track and ERA40 700 hPa heights and relative vorticity were then analyzed to determine on which, if any, days rainfall associated with the TC fell in the region. This analysis revealed 35 eastern Pacific TCs brought significant rainfall to the southwest US in the 46 years between 1958 and 2003.

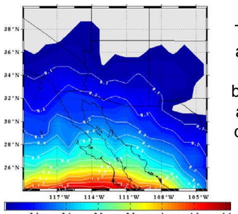
| Year | Storm Name | Dates | States with >25% of summer rain |
|---|---|---|---|
| 1958 | TS 10 | 9/10 – 9/14 | AZ CO NM UT |
| | H 11 | 10/4 – 10/6 | AZ |
| 1959 | H 10 | 9/11 – 9/15 | AZ CA NV |
| 1960 | H Diana | 9/11 – 9/15 | AZ CA NV |
| 1962 | TS Claudia | 8/19 – 8/23 | AZ CA NM NV |
| 1963 | TS Jen-Kath | 9/22 – 9/26 | AZ CA NV UT |
| 1965 | H Emily | 9/4 – 9/7 | UT |
| 1966 | H Kirsten | 9/28 – 10/2 | - |
| 1967 | H Katrina | 9/1 – 9/5 | AZ CA NV |
| 1968 | TS Hyacinth | 8/18 – 8/21 | AZ |
| | H Pauline | 10/2 – 10/5 | AZ CA UT |
| 1970 | TS Norma | 9/3 – 9/7 | AZ CO NM UT |
| 1971 | H Olivia | 9/29 – 10/1 | AZ CA CO NM UT |
| 1972 | H Hyacinth | 9/6 – 9/10 | CA CO |
| | H Joanne | 10/5 – 10/7 | AZ CA CO NM UT |
| 1976 | H Kathleen | 9/10 – 9/12 | AZ CA NV |
| | H Liza | 10/1 – 10/3 | NV UT |
| 1977 | H Doreen | 8/15 – 8/18 | AZ CA NV UT |

| Year | Storm Name | Dates | States with >25% of summer rain |
|---|---|---|---|
| 1977 | TS Glenda | 9/26 – 9/28 | AZ |
| | H Heather | 10/6 – 10/8 | AZ CA |
| 1982 | H Olivia | 9/24 – 9/28 | CA NV UT |
| 1983 | H Manuel | 9/18 – 9/20 | CA |
| 1984 | H Marie | 9/9 – 9/12 | AZ CA NV |
| | H Norbert | 9/25 – 9/27 | AZ |
| 1986 | H Newton | 9/23 – 9/26 | AZ CA CO NV UT |
| 1989 | H Raymond | 10/4 – 10/6 | AZ CO NM |
| 1992 | H Lester | 8/21 – 8/25 | AZ CA CO NM UT |
| 1993 | H Hilary | 8/26 – 8/30 | AZ CA CO NM UT |
| 1995 | H Ismael | 9/14 – 9/16 | NM |
| 1996 | H Fausto | 9/14 – 9/16 | AZ UT |
| 1997 | H Nora | 9/24 – 9/27 | AZ CA UT |
| 1998 | H Isis | 9/3 – 9/7 | AZ CA NV UT |
| 1999 | H Hilary | 9/22 – 9/24 | AZ CA |
| 2003 | H Ignacio | 8/26 – 8/29 | AZ CA NV |
| | H Marty | 9/24 – 9/26 | AZ |

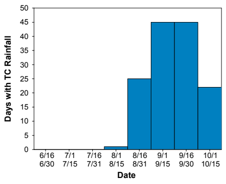
## Storm Climatology



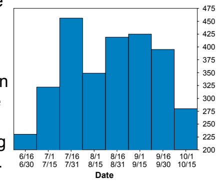


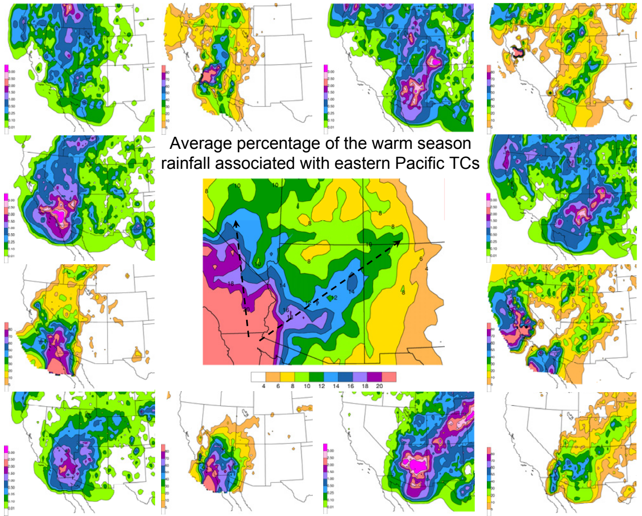


The tracks of the 35 TCs that brought rainfall to the US are shown to the upper left. The plot directly to the left shows that the return rate for a TC to the US/Mexico border is 5 years. The figure above shows the tracks of all eastern Pacific TCs that formed east of 160° W and did not cross 180° W between 16 June and 15 October 1958-2003. The tracks in red are 6% of all eastern Pacific TCs brought rainfall to the southwest US.




The bar graphs show the number of days TC rain occurred in the US, and the number of days at least one TC was active in the eastern Pacific. The most likely time for TC rainfall in the US is during the month of September.



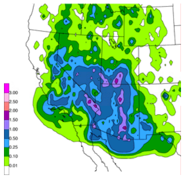



Average percentage of the warm season rainfall associated with eastern Pacific TCs

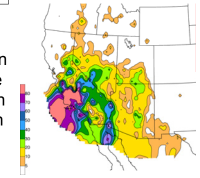
Examples of “California” track TCs are shown on the left, including H 10 (1959), Kathleen (1976), and Nora (1997). These storm are steered north under the influence of an anticyclone centered over central TX and/or a cutoff cyclone off the CA coast.

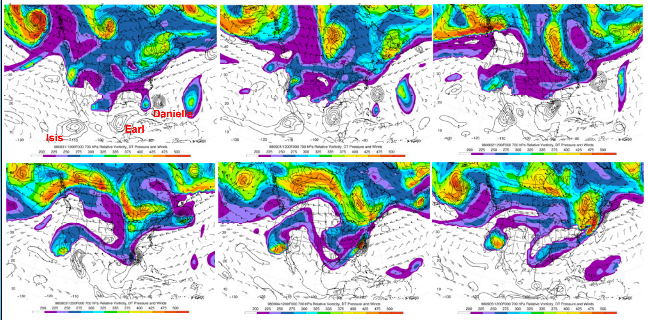
Examples of the “Northeast” track TCs are shown on the right, and feature Norma (1970), Olivia (1971), and Lester (1992). These storms interact with progressive mid-latitude troughs and are steered towards the northeast.

## Hurricane Isis (1998)



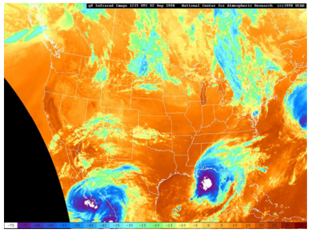
The rainfall distribution for Isis (1998) looked like a “California” track event. However, examination of a series of dynamic tropopause (DT) maps revealed the interaction between Isis and a disturbance on the DT, that was not evident on standard 500 hPa maps.

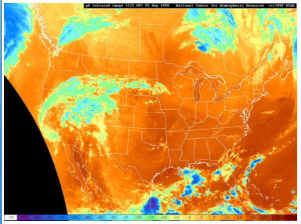





Even though NHC declared Isis dissipated at 00 UTC 9/4, the 700 hPa vorticity center clearly traveled up the Gulf of California and possibly redeveloped at the northern end of the Gulf due to lee cyclogenesis and convection.

Diabatic outflow from Isis eroded the PV strip connecting the California DT disturbance to the flow, amplified the downstream ridge-trough pattern and jump started the trough interaction and eventual extratropical transition of Earl.





The remnant Isis vorticity moved northeast towards the DT disturbance and cyclonically rotated around the disturbance, eventually merging with low level vorticity to the southwest of the disturbance.

## Summary and Future Work

- 35 eastern Pacific TCs brought significant rainfall to the southwest US between 1958 and 2003, representing just 6% of TC activity in the basin
- On average, 10-15% of the summer rainfall is contributed by TCs with the influence of TC rainfall increasing from east to west across Arizona
- Two main tracks for TCs into the monsoon region: 1) south to north path into California and Nevada, and 2) southwest-northeast “recurvature” track through Arizona, New Mexico and Colorado
- Construct synoptic scale composites for the two main track types
- Examine the interaction between eastern Pacific TCs and disturbances on the DT, i.e. extratropical transition, development of cutoffs, and downstream development