

Past and Future Rainfall from Dissipating Tropical Cyclones in Southwestern California

Jim Means

WeatherExtreme Ltd. / California State University, San Marcos

jim@weatherextreme.com

Michael Burin

California State University, San Marcos

Fernando de Sales

San Diego State University

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Abstract

While California is not normally thought of as a region affected by tropical cyclones, approximately one per year sends enough moisture northward to produce rainfall in California, typically during the late summer or early fall. The precipitation from these systems can be significant for two reasons: it can produce thunderstorms that may become severe and produce flash flooding, and even when the precipitation is more stratiform and less intense, it can delay the start of the fall fire season. In this investigation, we examine in detail the effects of several tropical cyclones on southwestern California, including Odile in 2014 and Dolores in 2015. The storms are analyzed through both observations (rain gauges and radar) and high-resolution WRF modeling in order to better understand the dynamics and moisture distribution that leads to precipitation. The two events produced markedly different weather: Odile generated severe thunderstorms with strong downdrafts while Dolores was a more widespread rain producer capable of localized flooding. This work represents the beginning of a broader study of dissipating tropical cyclones in California, including numerical experiments to examine how these systems may evolve differently under a future warmer climate.

1. Introduction

While California is not normally thought of as a region affected by tropical cyclones, about one per year sends enough moisture northward to produce rainfall in California, typically during the late summer or early fall. The precipitation from these systems can be significant for a couple of reasons: (1) it can produce thunderstorms that may become severe and produce flash flooding and (2) even when the precipitation is more stratiform and less intense, it can delay the start of the fall fire season.

In this investigation we look in detail at the effects of several of these tropical cyclones, including Odile in 2014 and Dolores in 2015. The storms are examined through both observations (gauges and radar) as well as high-resolution WRF modeling in order to better understand the dynamics and moisture distribution that leads to the precipitation. This is the beginning of a broader study

of the effects of these dissipating cyclones in California and the implications for a future warmer climate.

2. Hurricane Odile (September 2014)

2.1 Synoptic Setup

The track of Odile and the 500 hPa situation on September 16, 2014 is shown in Figures 1 and 2. Odile followed a mostly northwestern track over most of its existence, before recurving over the Baja California peninsula and dissipating as a remnant low over the Gulf of California and mainland Mexico. There is a deep trough west of California — for this early in the season, but in a fairly typical position — for drawing tropical cyclones northward and recurving them.



Figure 1. Track of Hurricane Odile, 10–18 September 2014.

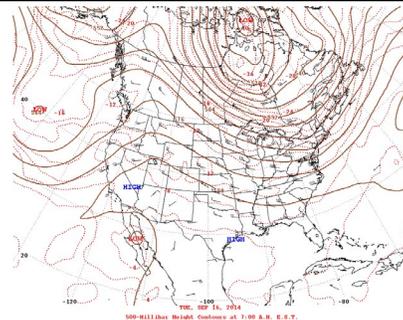


Figure 2. 500-millibar height contours at 07:00 A.M. EST, Tuesday, 16 September 2014, showing the synoptic setup during Odile's interaction with the southwestern United States.

2.2 Observations

Flow around the upper-level expression of Odile brought ample moisture into Southern California at mid-levels, while a relatively dry, shallow, northwesterly flow was seen at low levels. This produced an "inverted-V" sounding that is often associated with strong downdrafts, and that is exactly what occurred. The sounding, analyzed in RAOB (Figure 3), shows a substantial amount of convective available potential energy (CAPE) of over 700 J/kg. While that is large, it is much smaller than the amount of potential energy available for downdrafts (DCAPE), which has a value of over 1600 J/kg, yielding a thermodynamic potential downdraft velocity of over 50 meters per second.

This potential was realized when thunderstorms formed in the foothills near the convergence line between the shallow westerly flow and mid-level easterly flow, then propagated westward into the coastal regions. With the dry lower levels and somewhat spotty thunderstorm coverage, rainfall totals were not that great, totaling just under one inch at the rainiest location. Nevertheless, localized flooding occurred as the rain fell in a very short time period. The NEXRAD radar image (Figure 4) depicts the distribution of convection at 20:34 UTC on September 16, 2014.

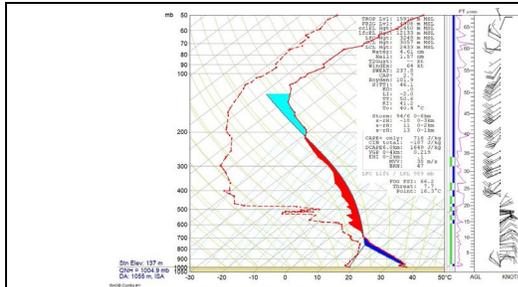


Figure 3. RAOB sounding analysis for San Diego during Odile, showing the inverted-V profile with CAPE of 716 J/kg and DCAPE of 1649 J/kg indicative of strong downdraft potential.

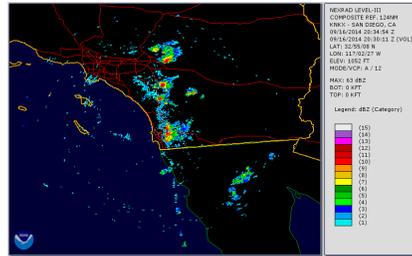


Figure 4. NEXRAD Level-III composite reflectivity from KNKX (San Diego), valid 20:34:54 UTC, 16 September 2014, showing the distribution of convective cells associated with Odile.

The photographs in Figures 5 and 6 illustrate the observed impacts. Figure 5 shows one of the wet microbursts that formed, while Figure 6 depicts damage at Montgomery Field, a general aviation airport, where several aircraft were damaged on the ground as a result of the strong downdraft winds.



Figure 5. A wet microburst associated with thunderstorms spawned by Odile. (Photo courtesy Mary Lakatos)



Figure 6. Aircraft damage at Montgomery Field general aviation airport resulting from microburst winds during the Odile event. (Photo courtesy Jonathan Auld)

3. Hurricane Dolores (July 2015)

3.1 Synoptic Setup

The 500 hPa situation on July 18, 2015 is shown in Figure 8. The mid-level low associated with Dolores lies at approximately 22°N, 118°W, well to the south of Southern California. An interesting and unusual synoptic setup is apparent. Southern California lies in a geopotential height col, with the East Pacific High offshore and displaced northward, while the far western edge of the Bermuda High is to the southeast. A positive-tilt trough extends southwestward from Canada, while the subtropical Eastern Pacific is relatively featureless except for the low associated with Dolores.

This synoptic setup is ideal for flooding tropical moisture northward from the dissipating tropical system into Southern California, advecting moisture first to the northwest offshore from Baja California and then turning back to the northeast and impinging the moisture on California — a situation something similar to an atmospheric river.



Figure 7. Track of Hurricane Dolores, 11–18 July 2015.

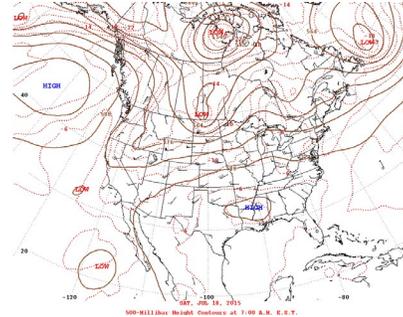


Figure 8. 500-millibar height contours at 07:00 A.M. EST, Saturday, 18 July 2015, showing the unusual synoptic configuration that channeled tropical moisture into Southern California.

3.2 Observations

The synoptic situation with Dolores is much different than that of Odile, and leads to substantially higher precipitable water, with the additional moisture at the lower levels. Analysis of the San Diego sounding in RAOB (Figure 9) shows 5.4 cm for Dolores versus 4.6 cm for Odile. In general the sounding is closer to a tropical air mass sounding with CAPE throughout a deep level, leading to a value that is about twice as high at 1452 J/kg. For the location, this value is climatologically quite high.

The lack of the dry air mass at low levels eliminates the strong downdrafts, with DCAPE of only 124 J/kg. Not surprisingly, over the course of a couple days, strong thunderstorms occurred with heavy precipitation that broke records for July. The NEXRAD radar image (Figure 10) shows the broad areal coverage of precipitation associated with Dolores, while Figure 11 presents the NCEP Stage-IV 48-hour quantitative precipitation estimate (QPE), with point totals exceeding 4 inches in some locations.

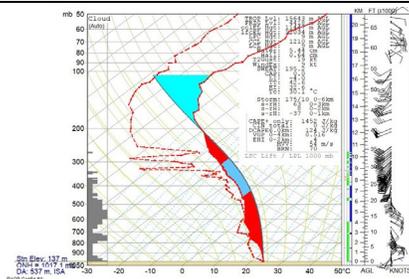


Figure 9. RAOB sounding analysis for San Diego during Dolores. Note the deep, moist profile with CAPE of 1452 J/kg and very low DCAPE of 124 J/kg, contrasting sharply with the Odile sounding.

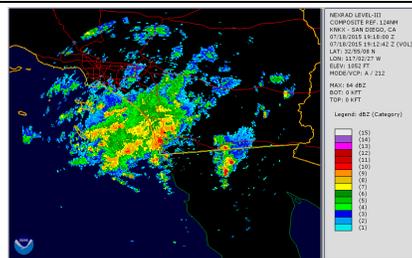


Figure 10. NEXRAD Level-III composite reflectivity from KNKX (San Diego), valid 19:18:00 UTC, 18 July 2015, showing the widespread precipitation coverage associated with Dolores.

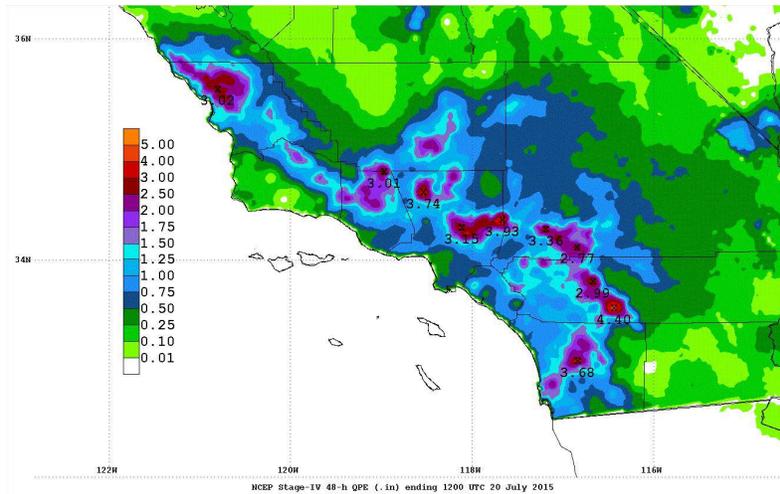


Figure 11. NCEP Stage-IV 48-hour quantitative precipitation estimate (inches) ending 1200 UTC, 20 July 2015, showing widespread rainfall across Southern California. Selected gauge reports are marked with ×.

4. Conclusions and Future Directions

Dissipating tropical cyclones can be an important source of warm-season rainfall and significant weather to Southern California. Additionally, the precipitation they provide can delay or mitigate some of the threat from the fall wildfire season. Here we have examined two storms that each produced significant weather in Southern California. The synoptic situation and weather they produced were quite different: Odile produced severe thunderstorms with strong downdrafts, while Dolores was a more widespread rain producer, even producing localized flooding.

These are just two of a number of tropical cyclones that have affected Southern California. We are undertaking a thorough investigation of all of them in recent decades, including high-resolution WRF modeling as well as looking at how their rainfall may or may not affect the ensuing fire season. Additionally, we are running numerical experiments to see how these storms might evolve and impact California differently in a future warmer climate with higher sea surface temperatures.

Acknowledgments

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