Poster 1491: Past and Future Rainfall from Dissipating Tropical Cyclones in Southwestern California

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Abstract

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.Background

Dolores formed as a tropical storm on July 11, 2015, reached Category 4 peak intensity on July 15, and was downgraded to an extratropical remnant low on July 19. The storm moved more or less northwesterly during its entire lifespan, becoming extratropical at approximately 25 N. As a named tropical system, it had no direct effects on Southern California in terms of winds or its spiral bands. Nevertheless, the unique synoptic setup advected large amounts of tropical moisture into Southern California. The timing of its path and intensity can be seen in Figure 1, which shows the track as determined by the National Hurricane Center.

Odile Synoptic Setup

The track of Odile and the 500 hPa situation on September 16, 2014 is shown below. 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.

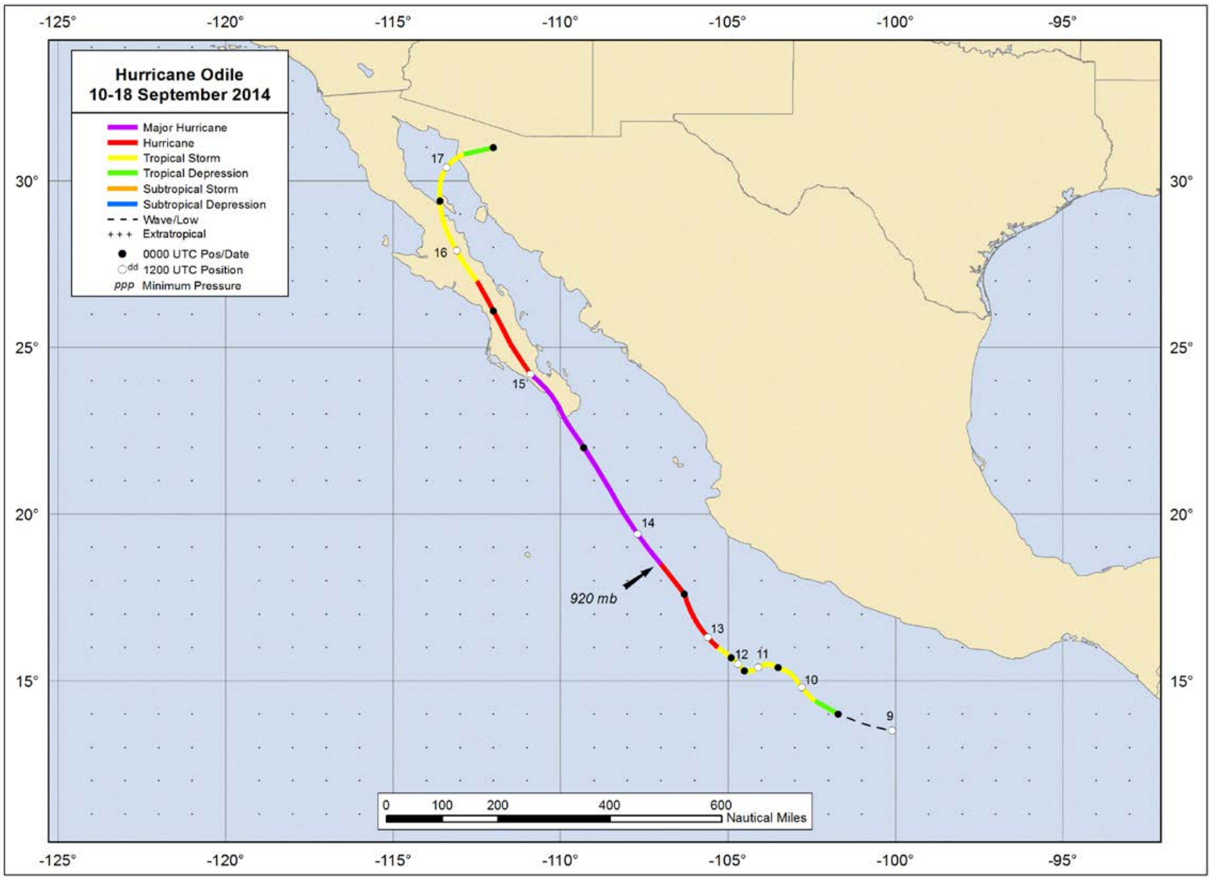

Figure 1: Best track positions for Hurricane Odile (Source: NHC)

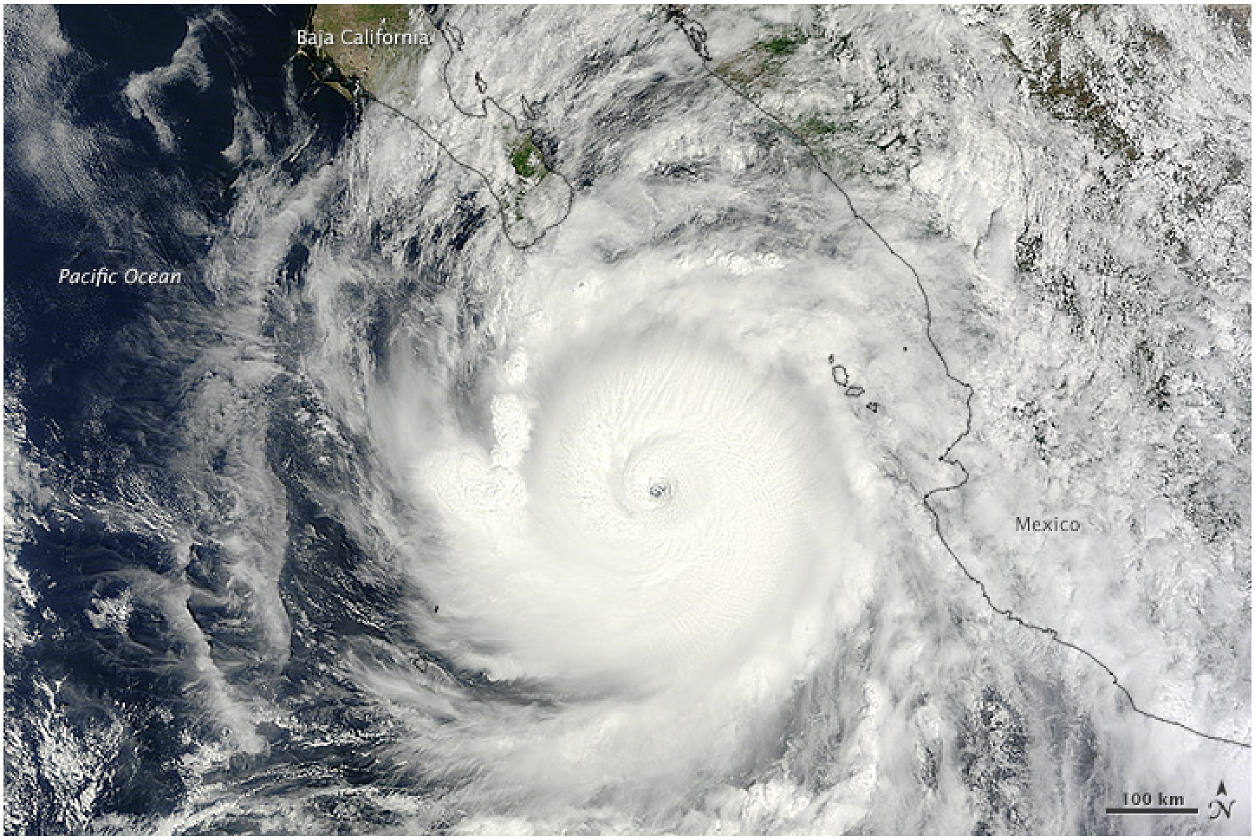

Figure 2. Hurricane Odile south of the tip of Baja California

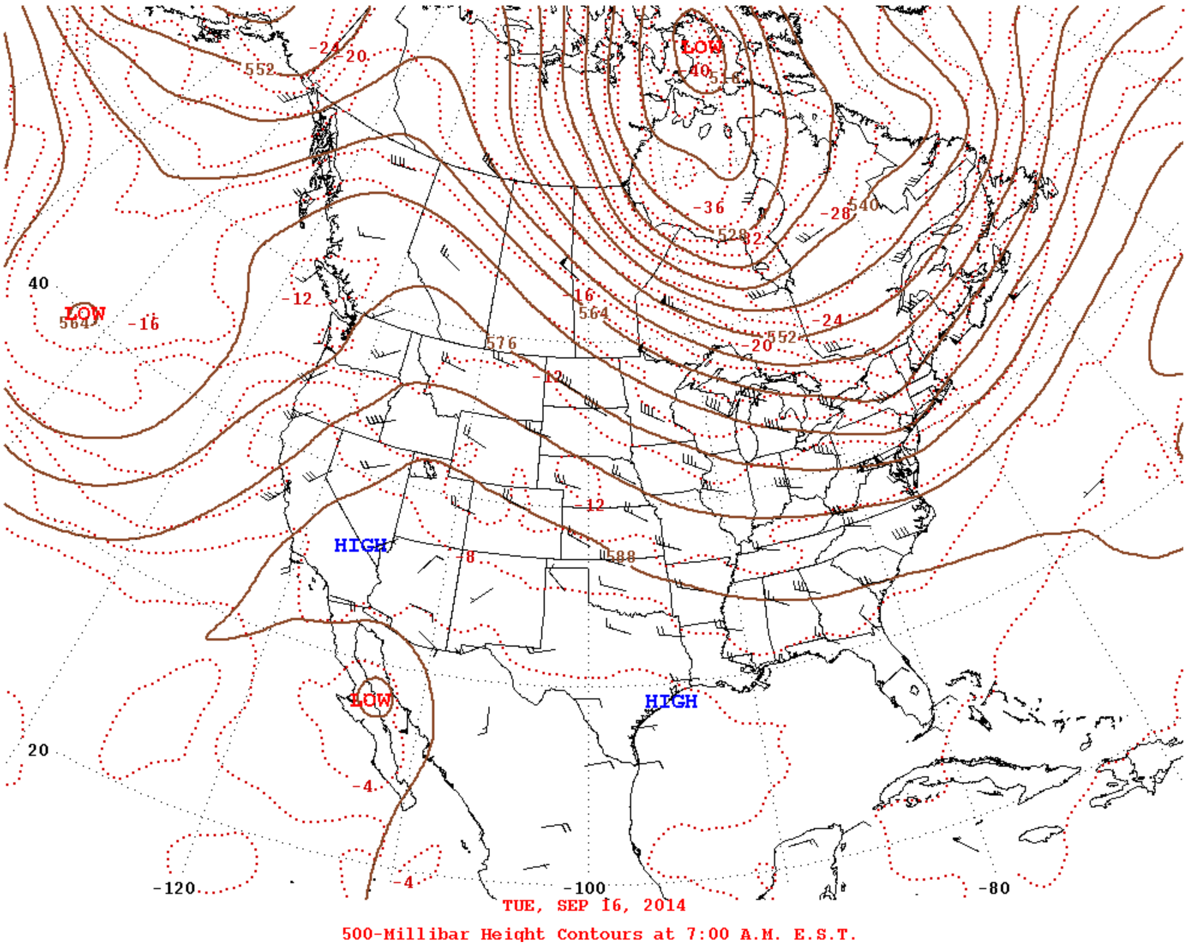

Figure 3. 500 hPa chart for 1100Z September 16, 2014

Figure 3 shows the 500 hPa situation on July 18, 2015. The mid-level low associated with Dolores lies at approximately 22N, 118W, well to the south of Southern California. An interesting an unusual synoptic setup is apparent, though. 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 perfect 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, in a situation something similar to an atmospheric river.

Observations

Flow around the upper level expression of Odile is bringing ample moisture into Southern California at mid-levels, while a relatively dry, shallow, northwesterly flow is seen at low levels. This produced to an “inverted-V” sounding that is often associated with strong downdrafts, and that is exactly what occurred. The sounding, analyzed in RAOB, 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/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. The photos show one of the wet microbursts that formed and some of the damage they caused at Montgomery Field, a general aviation airport, where several planes were damaged on the ground. 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.

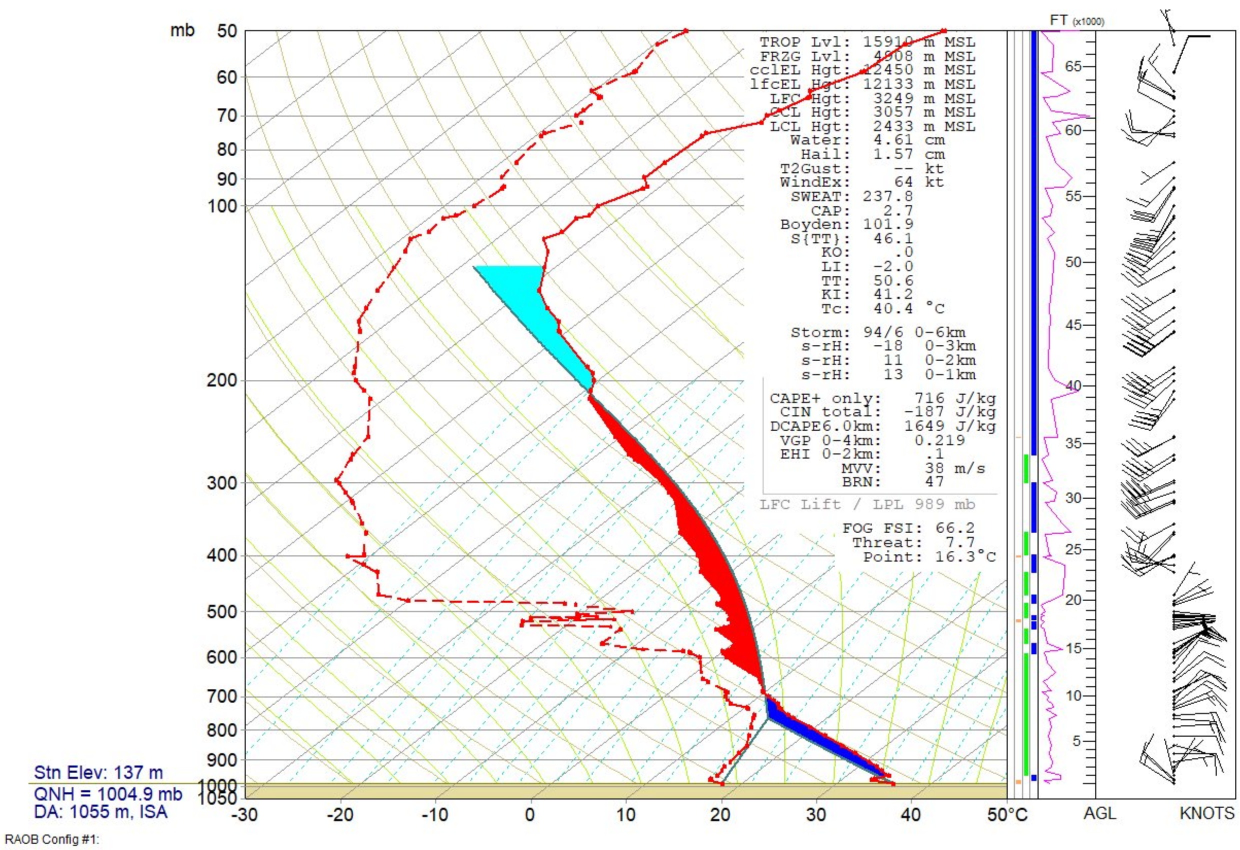

Figure 4: RAOB analyzed sounding for San Diego for September 17, 2014 at 00Z

The sounding shows easterly flow throughout the mid-levels of the atmosphere with a total of 46 mm of precipitable water with most of the moisture concentrated at the mid-levels. Lower levels are quite dry, with northwesterly flow at the lowest level. There is a substantial, but not extreme, amount of convective available potential energy (CAPE), which suggests the potential for thunderstorms. This setup leads to a classic “inverted-V” situation, which is evidenced in the downward convective available potential energy (DCAPE), with a magnitude of 1649 J/kg. This yields a thermodynamically derived maximum downdraft velocity of 57 meters/second, which suggests that damaging downdraft winds are possible.

Indeed, this is what occurred. During mid-morning hours, convergence along the horizontal shear line setup near the foothills between the northwesterly low-level winds and the mid-level easterly flow. High-based thunderstorms developed and were carried westward across the region. Strong microbursts formed bringing damaging winds to the coastal plains, an area that only rarely has strong thunderstorms.

Figure 5. Wet downburst associated with damage at Montgomery Field

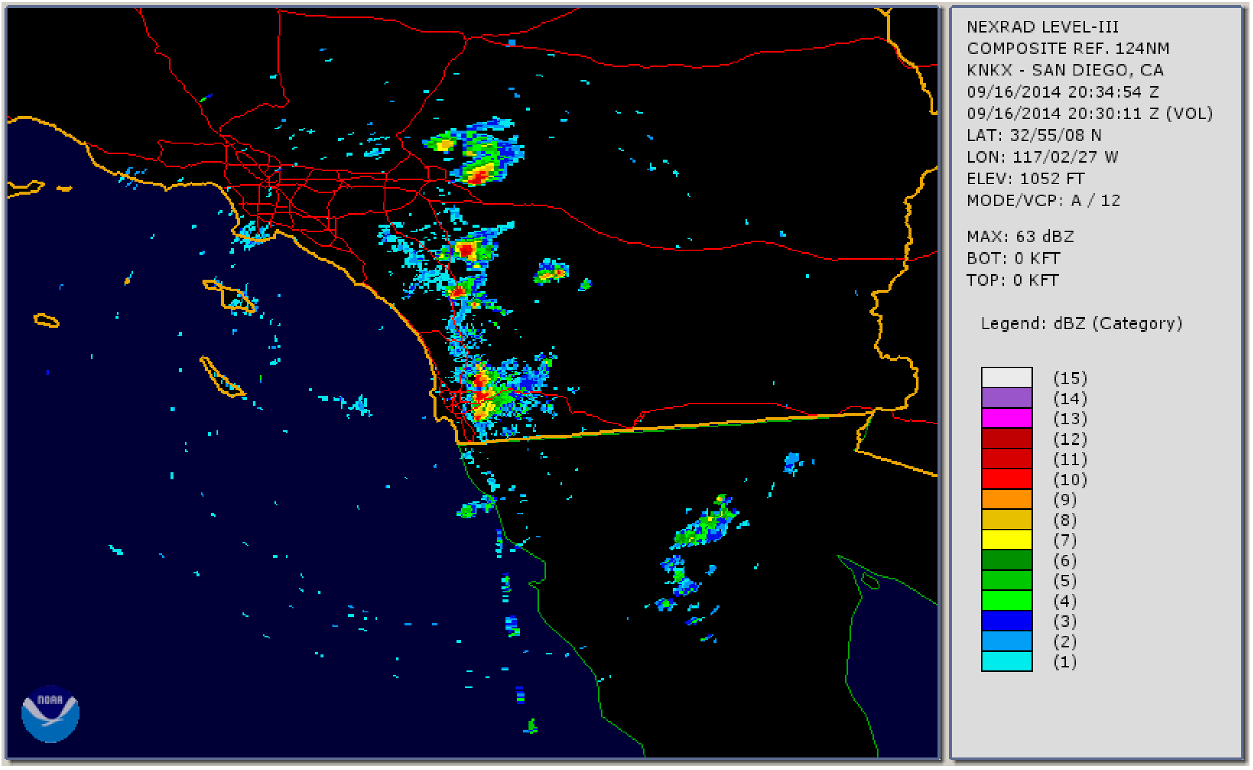

Figure 6. Level III Composite reflectivity shown severe storms over San Diego city

Figure 7a: Damage to airplane due to microburst

The situation was modeled with a set of three nested domains in WRF, as shown in Figure 3. The domains were chosen to be able to capture the broad-scale influence of Hurricane Dolores on its northwestward journey, while focusing in on details of the area of interest.

Figure 7b: Damage to airplane due to microburst at Montgomery Field

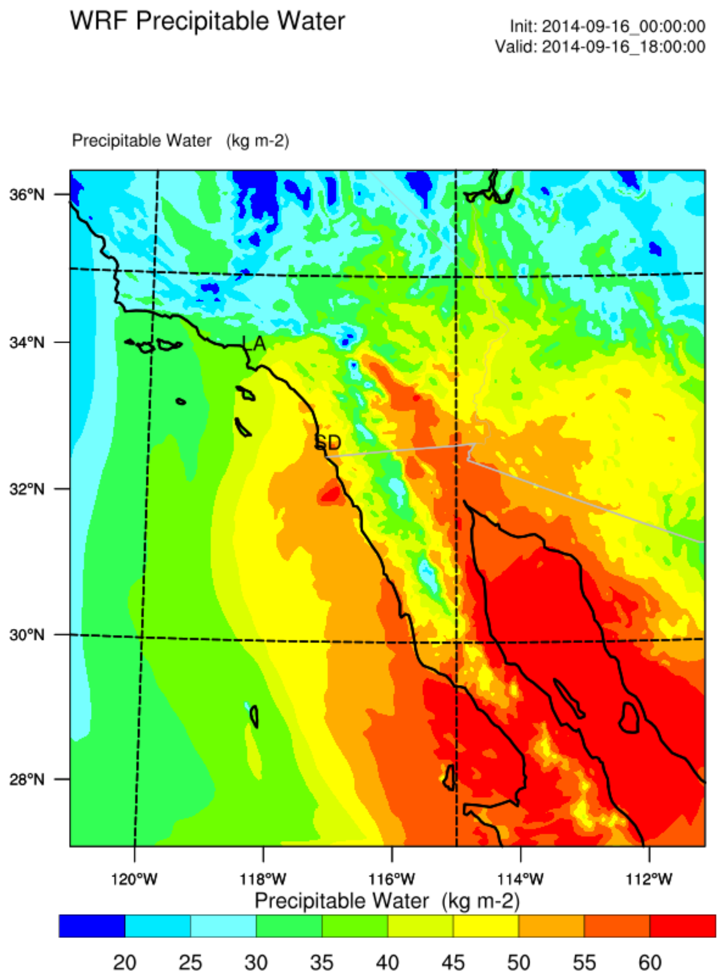

Figure 8. WRF modeled precipitable water associated with Odile

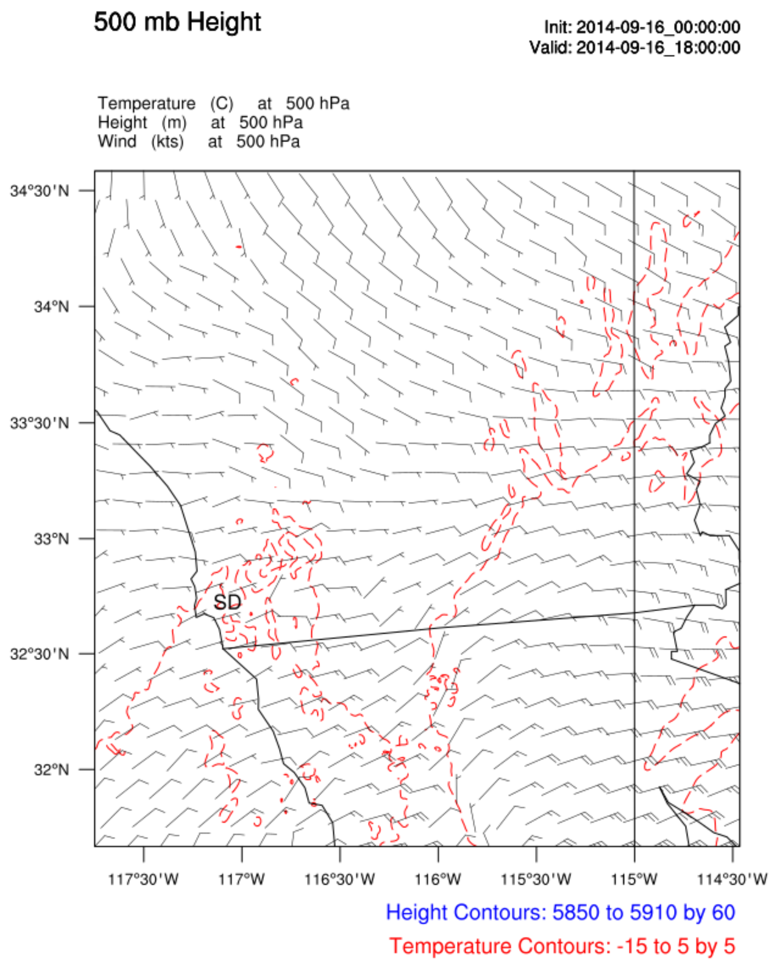

Figure 9. WRF modeled 500 mb winds associated with Odile.

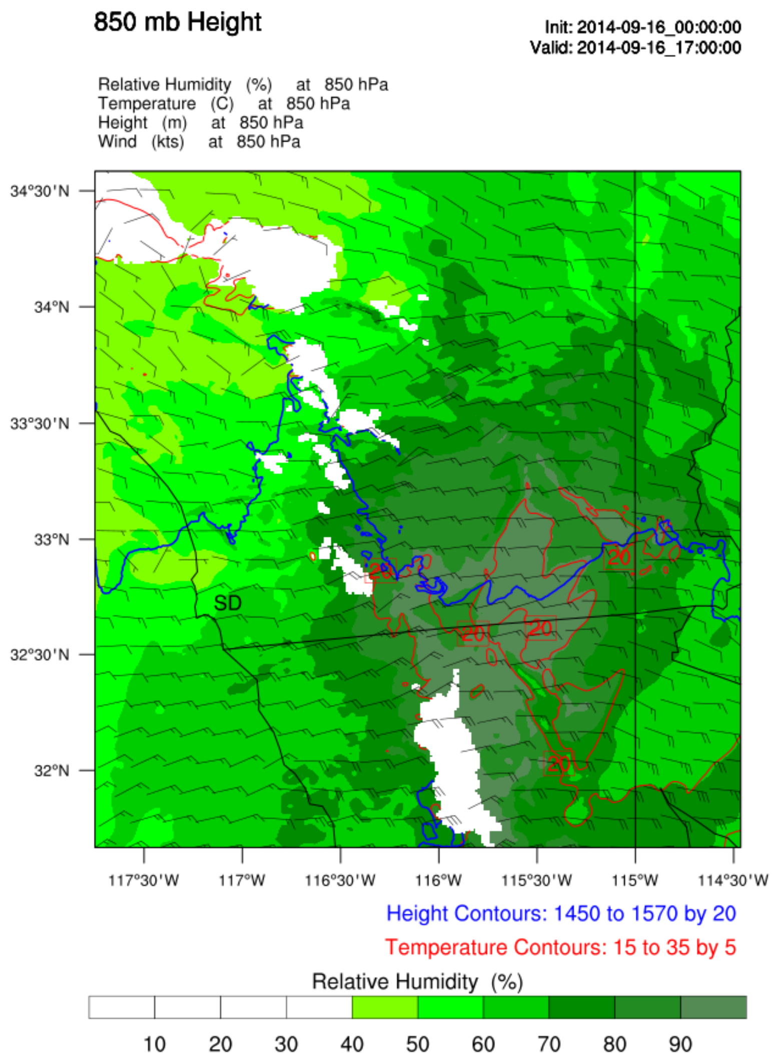

Figure 10. WRF modeled 850 mb winds and relative humidity associated with Odile.

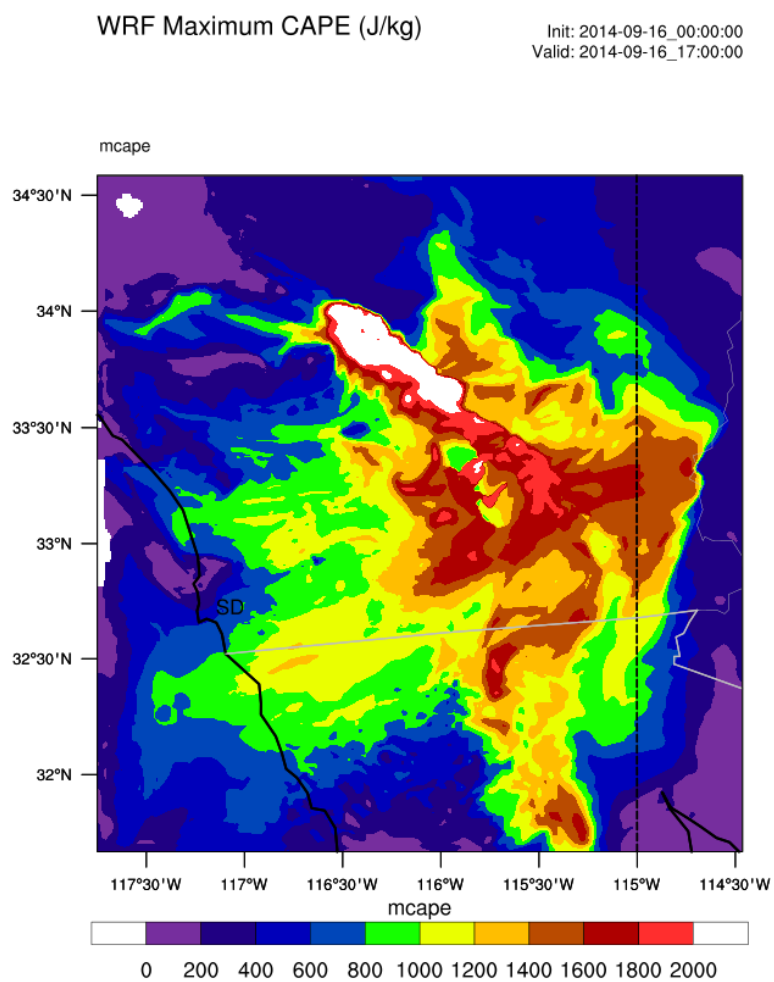

Figure 11. WRF modeled CAPE associated with Odile

Dolores Synoptic Setup

The 500 hPa situation on July 18, 2015 is shown below. The mid-level low associated with Dolores lies at approximately 22N, 118W, well to the south of Southern California. An interesting and unusual synoptic setup is apparent, though. 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.

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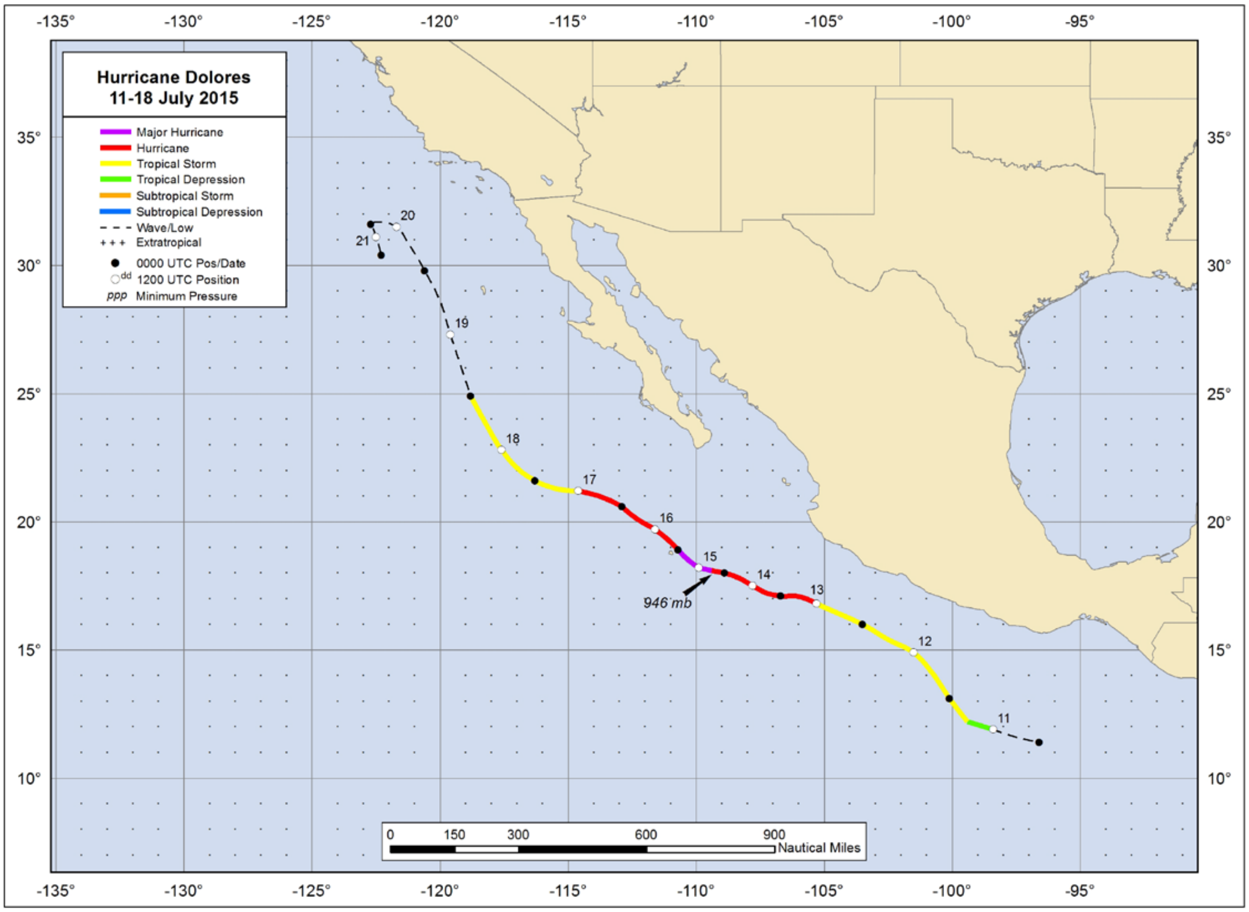

Figure 12. Track and Intensity Hurricane Dolores, July 11-18, 2015

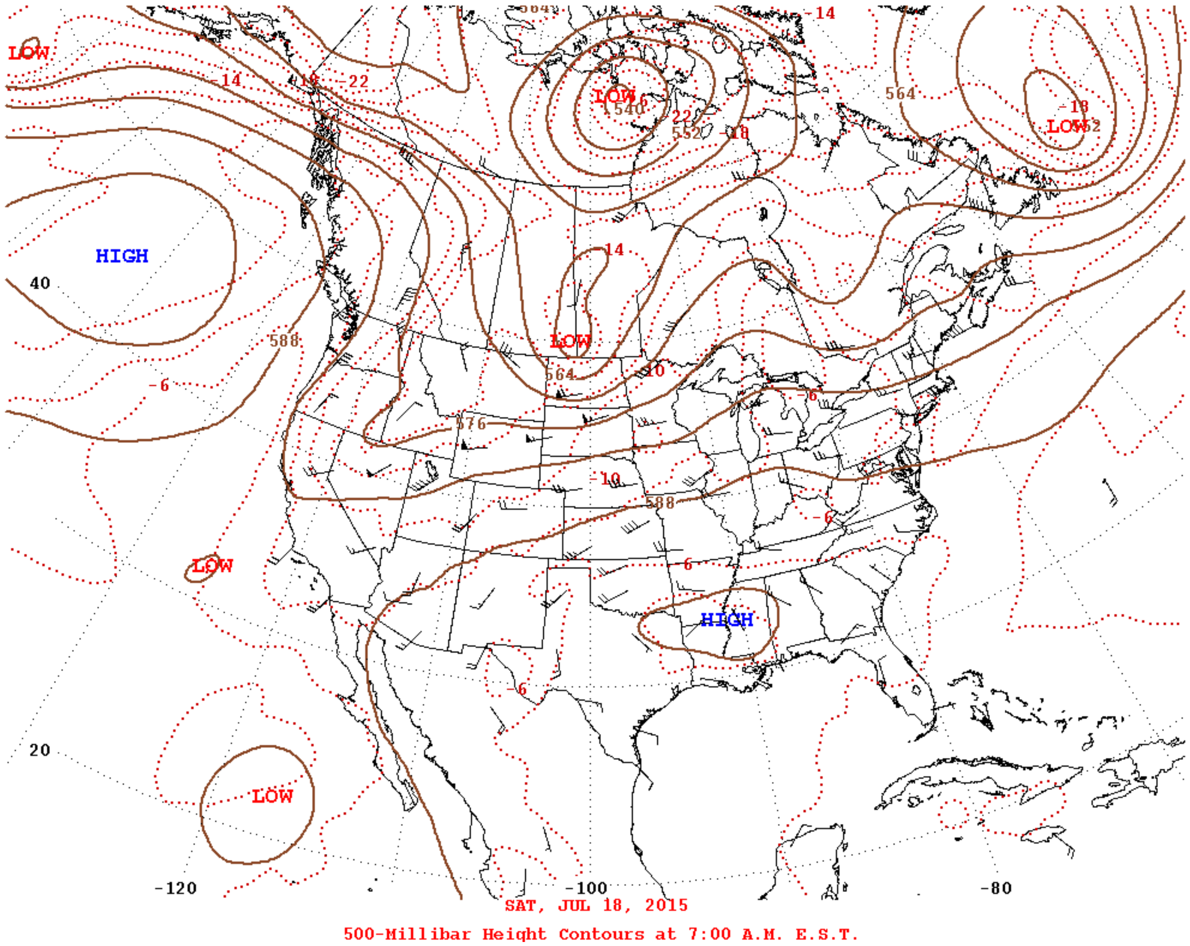

Figure 13. 500 mb synoptic situation associated with Dolores

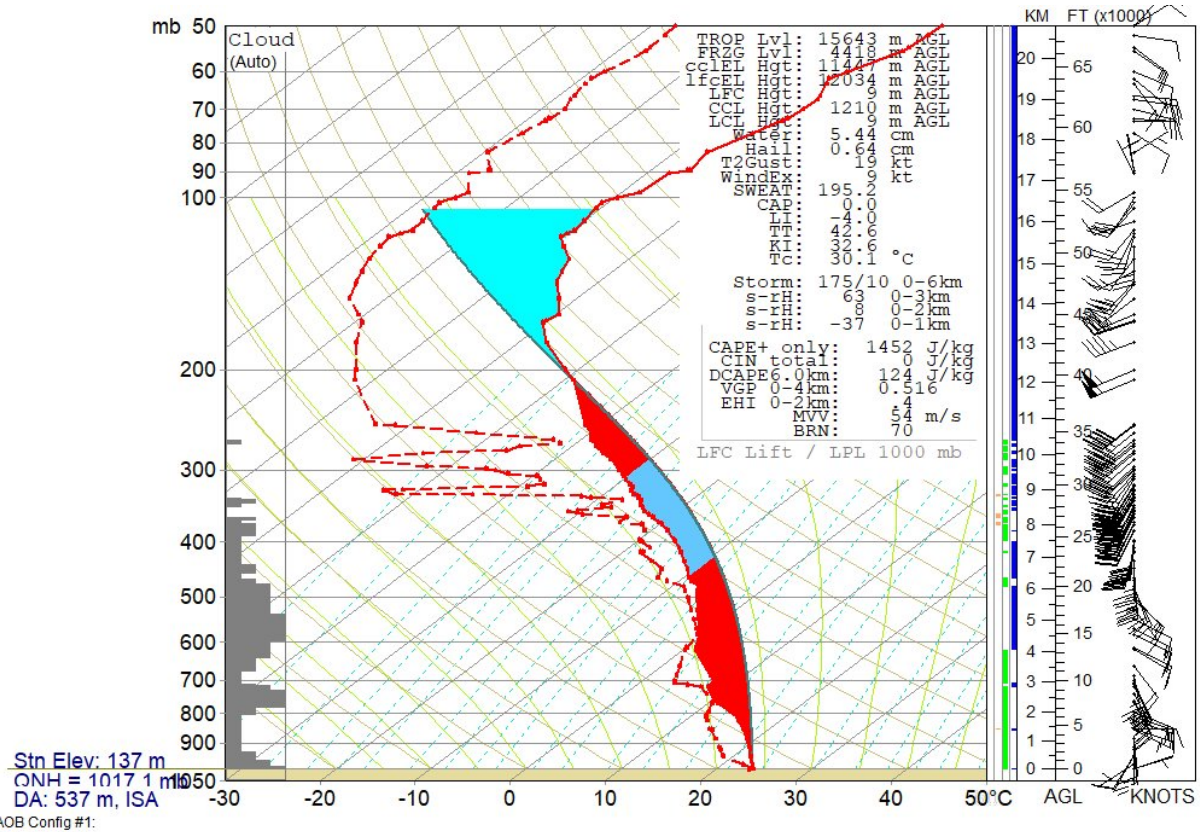

Figure 14. RAOB analyzed sounding for San Diego, CA on 7/19/2015 12Z associated with Dolores

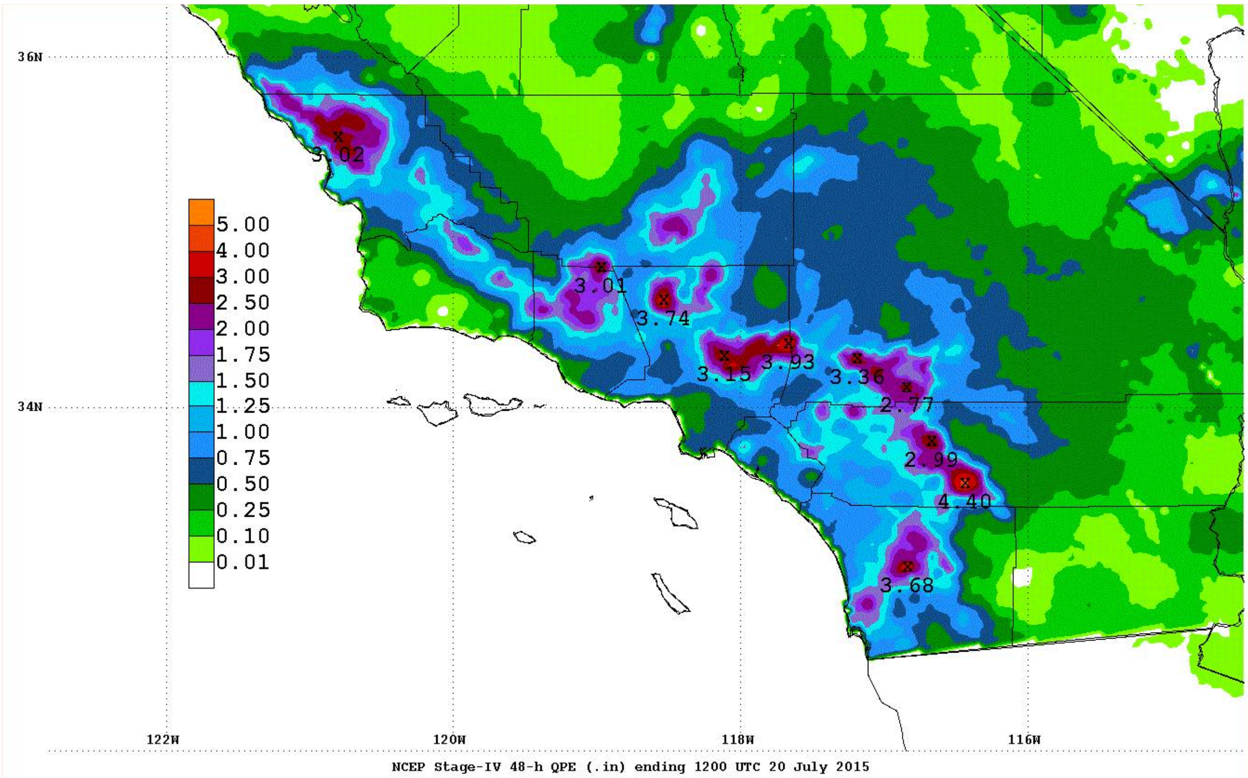

Figure 15. NCEP-analyzed rainfall totals over Southern California from Dolores

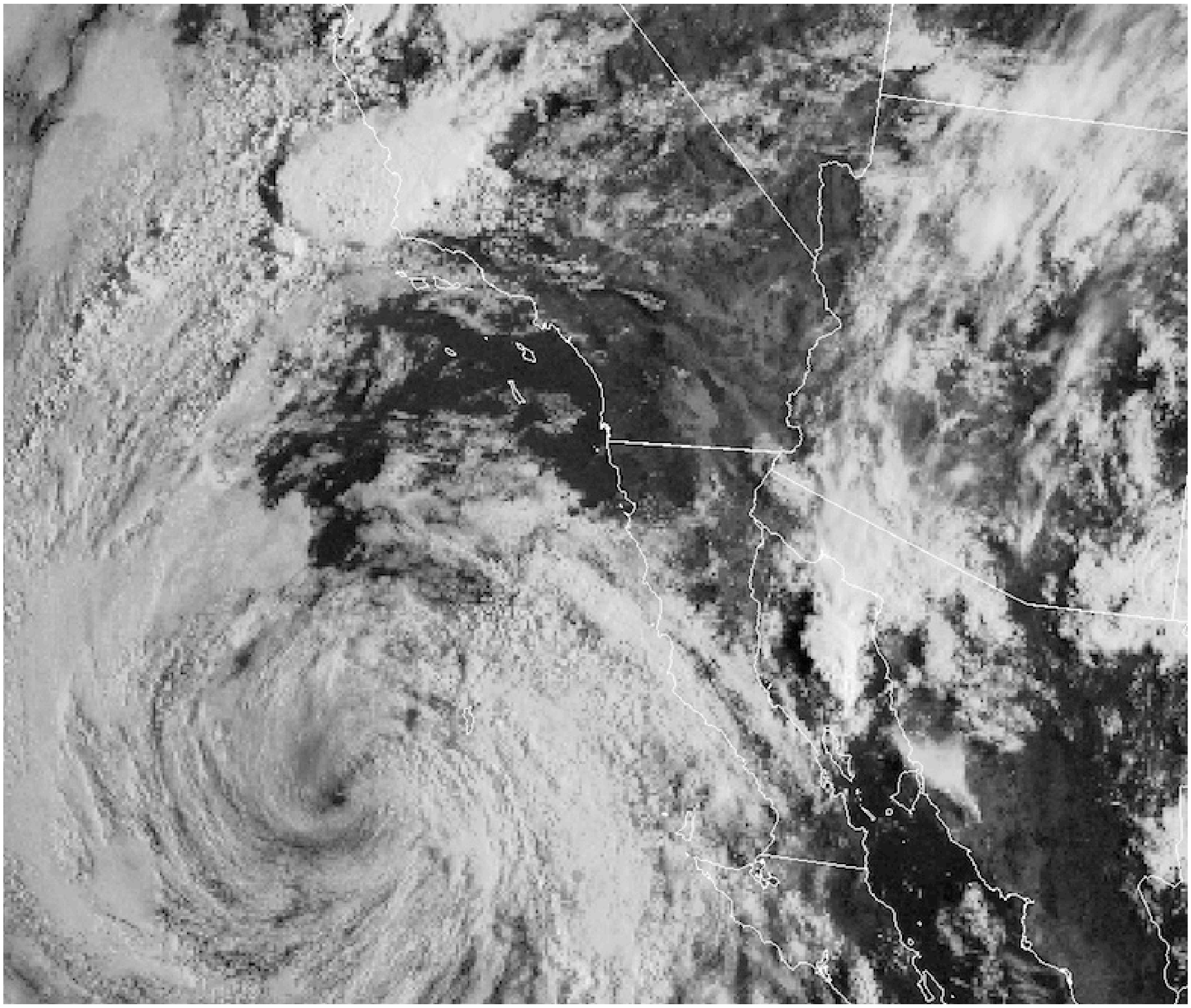

Figure 16. Remains of Dolores dissipating southwest of San Diego

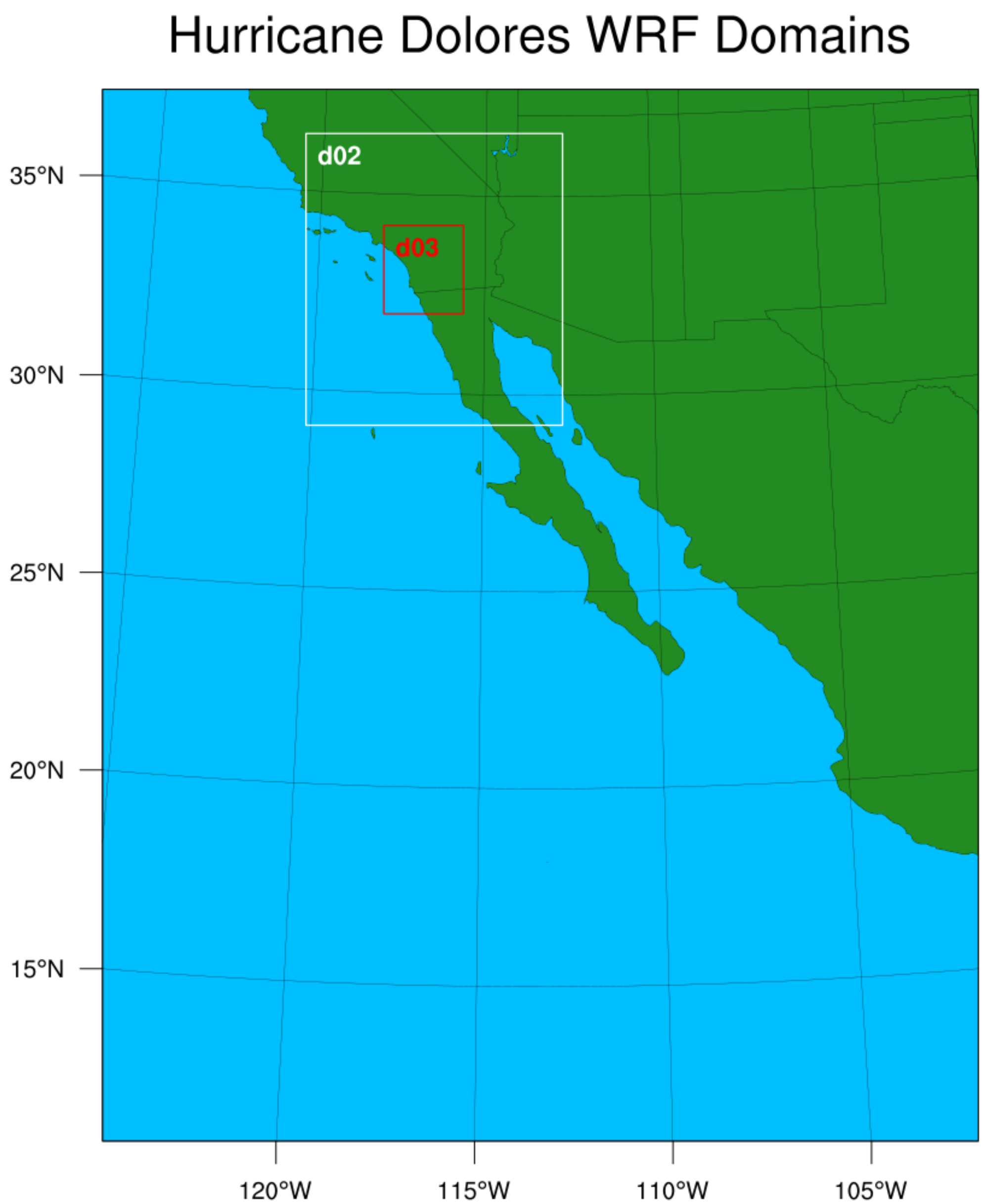

Figure 17. Nested WRF Domains

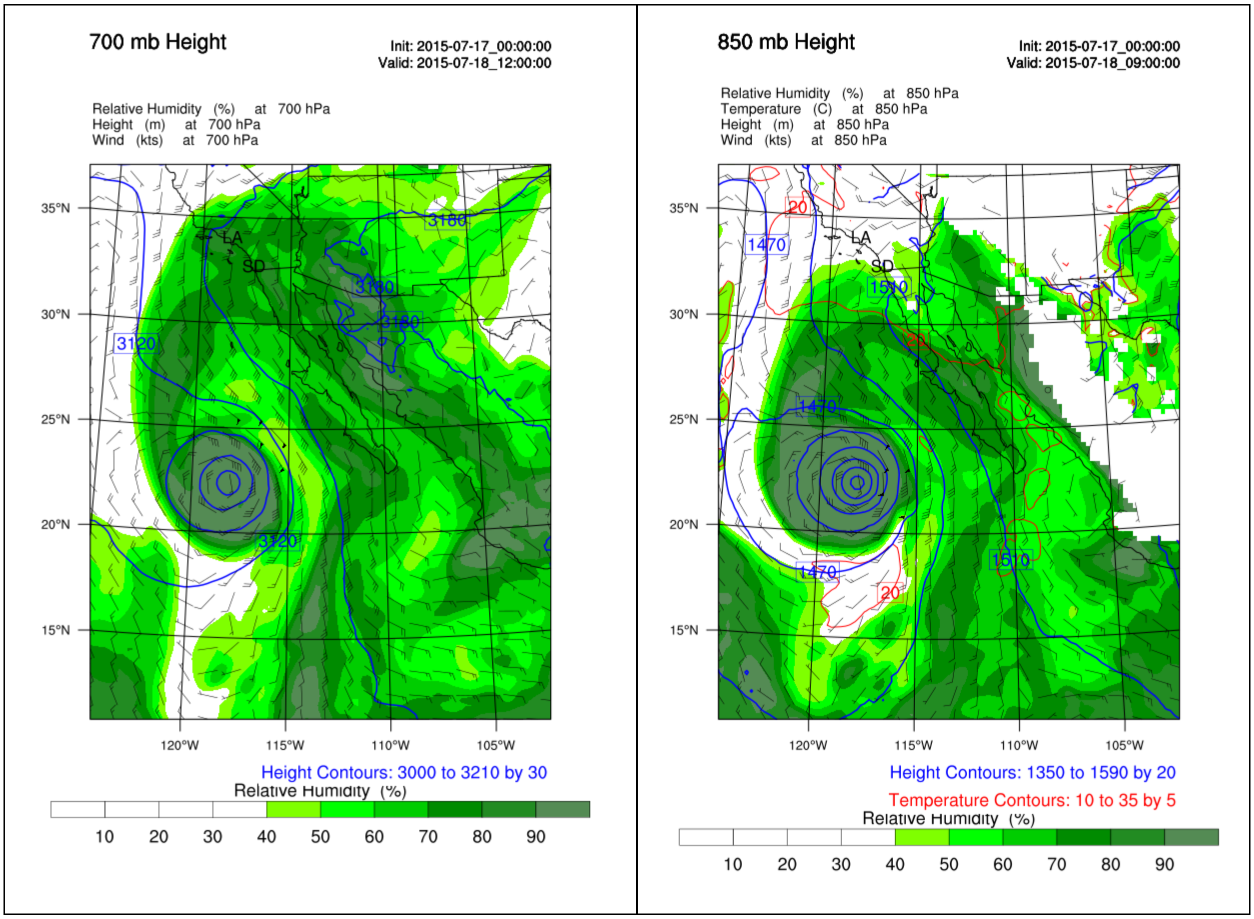

Figure 18. 700 and 850 hPa height and relative humidity associated with Dolores

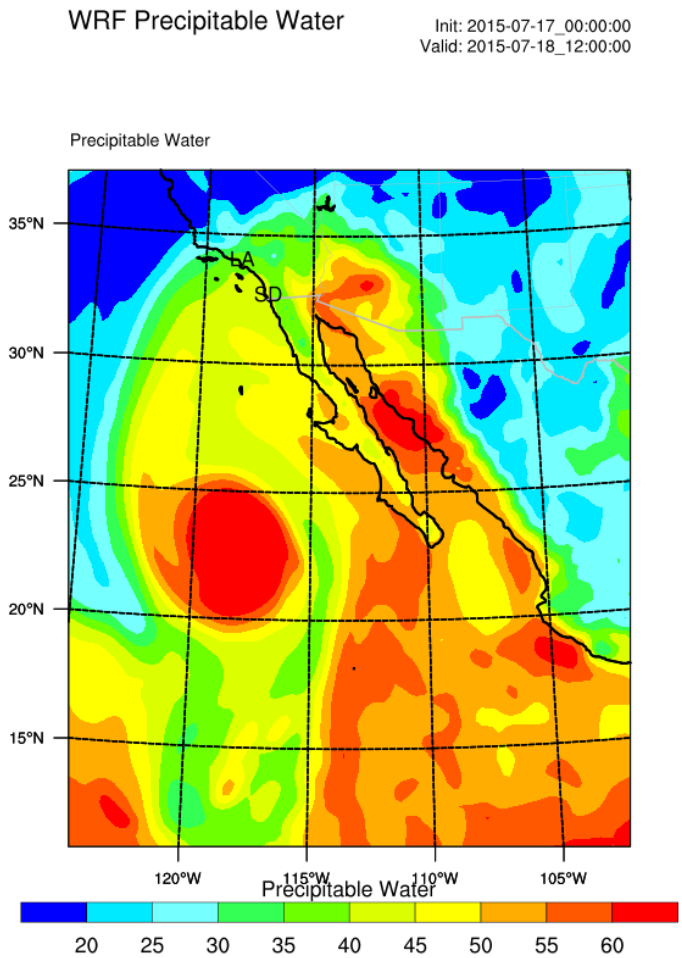

Figure 19. WRF Precipitable water for outermost domain associated with Dolores

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 producing 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.