# 18.B5 UNIQUE IMPACTS FROM HILARY IN THE UNITED STATES

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## 1. SYNOPTIC HISTORY

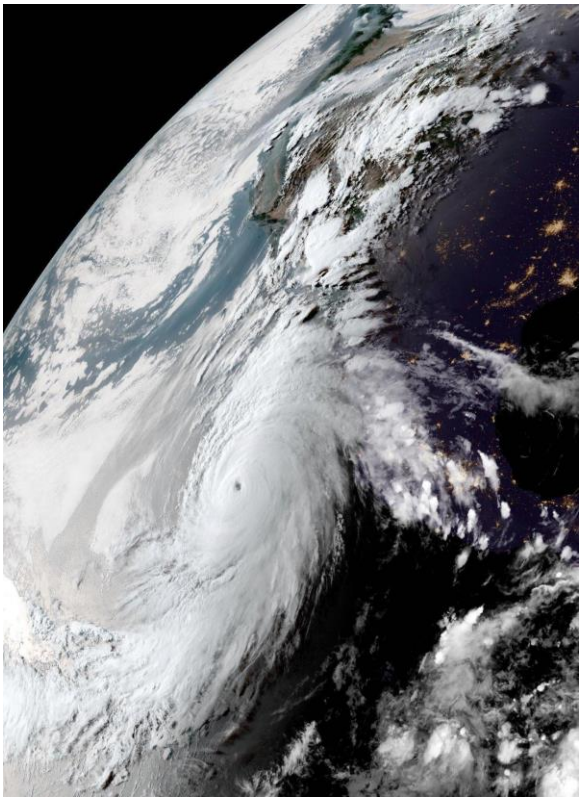

***Figure 1. GOES-East RGB band satellite image of Hurricane Hilary on the evening of August 18, 2023***

Hilary was a hurricane that briefly became intense offshore of southwest Mexico from late on August 17 through August 18, 2023. The system recurved north-northwest to the southeast of an anomalously strong upper level trough near the California coast, experiencing vertical wind shear as it moved into the state of Baja California across northwest Mexico. In post-analysis, the National Hurricane Center (NHC) declared Hilary a post-tropical remnant low on the afternoon of August 20 with its original well-defined center dissipating (Reinhart 2024).

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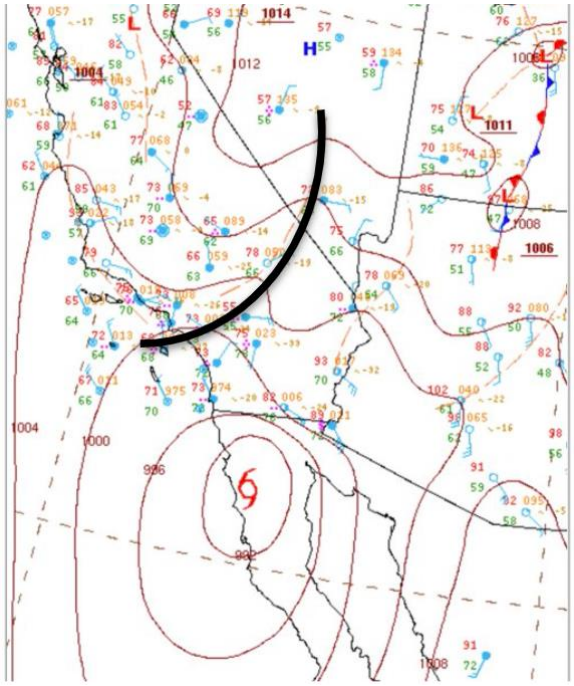
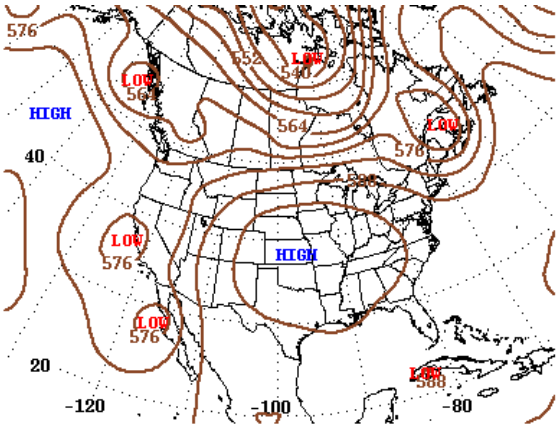


***Figure 2. The August 20, 2023 2100 UTC Weather Prediction Center (WPC)/NHC TAFB surface analysis shows Hilary in the state of Baja California and a "steering line" across southern California and southern Nevada.***

However, the broader surface low associated with Post-Tropical Cyclone Hilary moved and/or propagated through far southern California, emerging briefly into the Southern California Bight before moving into Greater Los Angeles around 0300 UTC on August 21. The low nearly lost identity while it moved up the Sierra Nevada range, but it regained some definition across the Great Basin on the morning of August 22 before finally losing identity across Idaho during the afternoon on August 22. Near and ahead of Hilary, anomalous moisture brought heavy rainfall through portions of the normally arid western United States. The interaction between the upper level low which caused Hilary's

recurvature, the combined impact of the two systems on the Southwest, the downstream ridge and the heat wave under its base across the southern and central Plains were of interest.

## 2. UPPER LEVEL PATTERN NEAR CALIFORNIA




500-Millibar Height Contour at 7:00 A.M. E.S.T.

***Figure 3. The 500 hPa pattern at 1200 UTC on August 20, 2023 showing the major players near western North America. Hilary is approaching Baja California state at this time. Source: WPC Daily Weather Maps.***

An upper level low was first spotted near the California coast on August 10. Through August 16, the system moved northwestward offshore of California. Thereafter, 500 hPa ridging near the 50th parallel to the south of Alaska led to strengthening of the upper level low and caused the feature to drop back down the California coast through August 19. A deep layer cyclone moving down the coast of the Alaska Panhandle along with the breakdown of the ridge along the 50th parallel led to the northwest movement of the upper level low, which at that point had captured Hilary, with the two moving north-northwest in tandem.

The combination of the strengthening upper level low near the California coast and Hilary's attempt to phase with it, led to a strengthening of a downstream ridge across the central Lower 48 United States which aided a heat wave centered near Kansas between August 19 and August 25, 2023. High temperatures reached 46C at Manhattan, Kansas on August 19, which was the national high temperature for the United States that day (Weather Prediction Center 2023). The combination of the heat and the humidity lead to heat index values as high as 52C at Chanute, Kansas on August 21 (Wichita 2023).

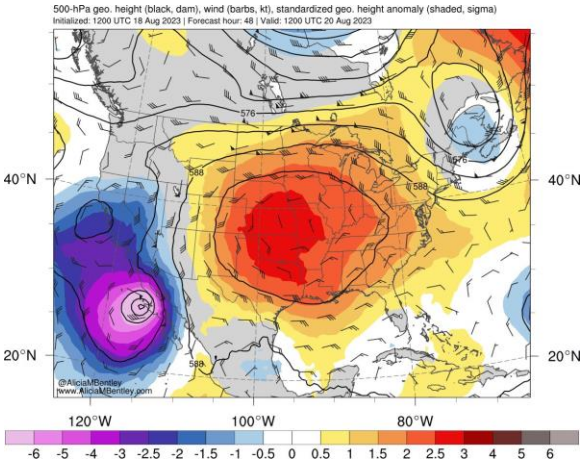



***Figure 4. Standardized anomalies forecast for 1200 UTC August 20, 2023 obtained from Alicia Bentley's real-time maps website. Note their strength near the upper low causing Hilary's recurvature and Hilary itself.***

The main problem along the West Coast, from a forecast perspective, was the timing of when and how far south the upper low near California was going to get, when it was going to capture Hilary, and when the systems would rebound north-northwest. This caused Hilary recurvature timing and location uncertainty about five days ahead of Hilary's approach to California, which became more or less resolved three days in advance of its former low's landfall.

Broadly available high resolution NCEP reanalysis datasets use a 31-year database (1979-2009); this misses the spate of tropical cyclone and tropical cyclone remnants that moved into California during the 1970's which likely makes moisture anomalies more extreme than they should be in unusual cases such as Hilary. Moisture variable distribution is non-standard, skewing towards low values, which also makes interpretation of standard deviations along the long tail of the distribution non-trivial.

The above combination led to extreme standardized anomalies for Integrated Vapor Transport (IVT) forecasts, a variable normally used for atmospheric river events in the West, across the Southwest. These anomalies would reach as high as 22 sigmas above the mean for mid- to late-August as the

forecast period shortened. The IVT values forecast – 1250+ kg/(ms) – would qualify the atmospheric river coming in from the Gulf of California as an exceptional event (Ralph 2019), one that is rare for August.

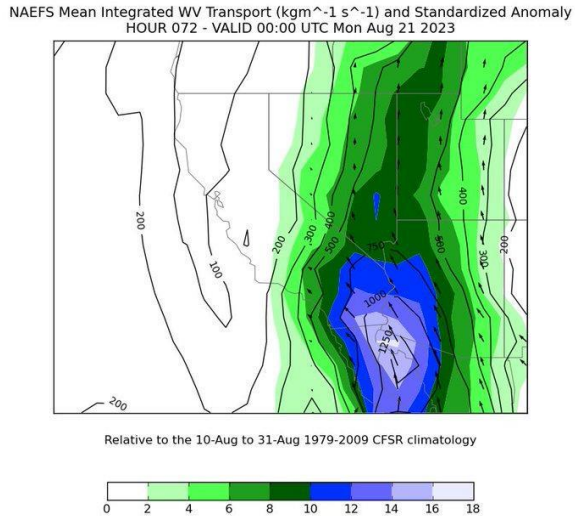



***Figure 5. IVT standardized anomaly forecast 72 hours ahead of Hilary's approach to the Desert Southwest. These anomalies would increase in later forecasts.***

### 3. NWS COLLABORATION AHEAD OF HILARY

Ahead of major weather events, National Centers within the National Weather Service (NWS) and local NWS forecast offices affected by the event coordinate messaging, such as heavy rainfall threat, the rainfall ranges used within the rainfall statement, and any related watches along with National Center Key Messages. Hilary was no different. WPC coordinated the various excessive rainfall threat levels with the southwestern U.S. offices in the days leading up to its incursion, particularly in the overnight issuances. This ultimately lead to a coordinated and unified set of flood and flash flood watches ahead of the storm and led to more unified messaging than may have occurred otherwise..

The year 2023 was the first season that the National Hurricane Center used Google Meet for conference calls with Southwest U.S. forecast offices. This allowed those offices to see folks from WPC and NHC for possibly the first time interacting within the NWS Tropical Program..

Other than the conference calls, AWIPS collaboration chat software was also used to coordinate conference call timing between WPC and the western U.S. forecast offices. Google Chat is used to coordinate rainfall messaging for NHC between WPC and the National Water Center.

### 4. HILARY'S IMPACTS

***Figure 6. The lakes of Badwater Basin in early December 2023, deposited by Hilary. Source: Andrew Hink.***

As Hilary moved near the coastal ranges of Southern California and moved up the Sierra Nevada, a broad area of heavy rainfall fell across the Desert Southwest as moisture and instability streamed in from the Gulf of California at a scale not seen since at least 1976. Heavy rains fell along the normally arid sides of the terrain, and across the deserts themselves. Some locations measured 1-2 years of annual average rainfall within a 24 hour period. For Badwater Basin itself, within Death Valley National Park, lakes formed in the wake of Hilary that persisted until February, when a significant atmospheric river recharged the lakes.

### 5. RECORDS SET

The previous time that tropical storm-force winds occurred in California from a tropical cyclone or remnant was during Nora's passage near the Lower

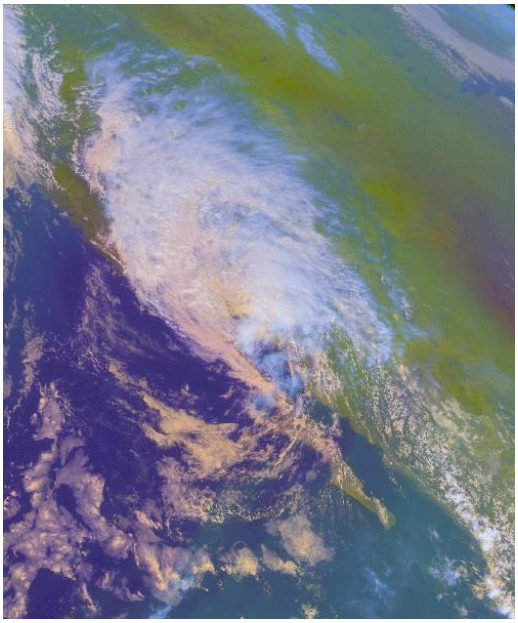


***Figure 7. GOES-West satellite image of Tropical Storm Nora moving into the Southwest U.S. on September 25, 1997.***

Colorado Valley in late September 1997. State rainfall records from a tropical cyclone, post-tropical cyclone, or remnant from an eastern Pacific tropical system were set across several western states from Nevada northward through the Pacific Northwest into Montana. Death Valley, California set a new all-time daily rainfall record when it received more rain on August 20 – 55.9 mm – than it averages over an entire year. The all-time daily rainfall record set by Hilary in Death Valley had just been set 13 months before; road damage at Death Valley National Park from the July 2022 heavy rain event and from Kay in September 2022 was still being repaired when Hilary's rains struck the area in August 2023. Los Angeles, San Diego, and Palm Springs (in California) saw their wettest summer day (June- August) on record. Several low mean sea level pressure records for the month of August were set near the coast of Southern California close to Hilary's track, including a couple at sites with longer databases that extend back into the nineteenth century (Los Angeles and San Diego). The upper trough that escorted Hilary inland also helped set August low pressure records much farther up the coast of California into Oregon, including one site (Eureka) with a database back into the late nineteenth century.

**August Record Low Sea Level Pressures Set By A Nearby Deep Layer Low & Hilary August 20-21, 2023**

| Location | Value | Previous Record | Date | Period of record |
|---|---|---|---|---|
| Brookings OR | 1005.0 hPa/29.68" | 1006.1 hPa/29.71" | 23rd/2007 | Since 1977 |
| Eureka CA | 1005.4 hPa/29.69" | 1005.8 hPa/29.70" | 28th/1951 | Since 1886 |
| Los Angeles CA | 996.3 hPa/29.42" | 1002.4 hPa/29.60" | 15th/1906 | Since 1893 |
| Monterey CA | 1004.1 hPa/29.65" | 1005.6 hPa/29.70" | 27th/1951 | Since 1939 |
| Point Arena CA | 1003.1 hPa/29.62" | 1005.4 hPa/29.69" | 28th/2021 | Since 1984 |
| San Diego CA | 997.3 hPa/29.45" | 1003.7 hPa/29.64" | 27-28th/1981 | Since 1872 |
| San Francisco CA | 1001.7 hPa/29.58" | 1002.4 hPa/29.60" | 27th/1932 | Since 1892 |
| San Nicolas Island CA | 999.8 hPa/29.52" | 1004.3 hPa/29.66" | 30th/2008 | Since 1943 |
| Vandenberg/Lompoc CA | 1001.1 hPa/29.56" | 1005.2 hPa/29.68" | 28th/1981 | Since 1957 |

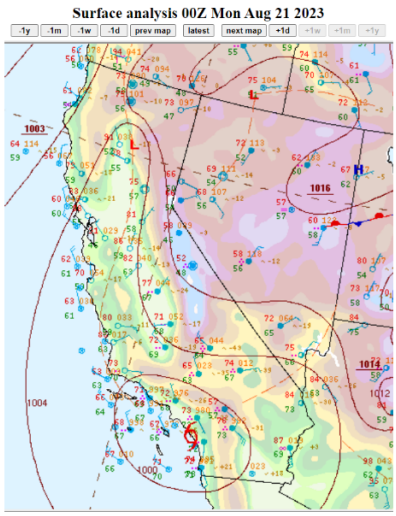



***Figure 8. August record low sea level pressures established due to both the upper low that escorted the Hilary low inland and Hilary itself.***


***Figure 9. The lakes which formed in Badwater Basin due to Hilary in August 2023 (middle image) were replenished by an anomalous atmospheric river in February 2024 (right image). Source: NOAA Earth Observatory***

## 6. POSSIBLE ROLE OF CLIMATE CHANGE

Both Hilary and Kay (in 2022) benefited from above average sea surface temperatures along their path. This likely kept the pressure in association with their low pressure systems lower, which would explain the monthly sea level pressures both systems set in

southern California for August (Hilary) and September (Kay) respectively. In Hilary's case, it likely contributed to its former low pressure area remaining a tropical storm-force cyclone on final approach to southern California. While the track of the low formerly associated with Hilary appeared more important for heavy rainfall concerns in normally arid regions of the western U.S, increasing sea surface temperatures within a warmer world would potentially bring stronger systems out of the tropics and more associated moisture and instability into the American Southwest in the future – and by proxy heavier rainfall within extreme events. The frequency of heavy rain events since 2022 in Death Valley may be a sign of such.

Rainfall amounts/intensity have been showing an increase across the Lower 48 United States since 1901, particularly during the fall season, due to climate change.. Climate model projections suggest that even when tropical and post-tropical cyclone impacts show little change in frequency when compared to past years, rainfall from such systems is expected to rise 8-17%. (Easterling et. al 2017). In the wake of exceptional heavy rain events in the Carolinas (Hurricane Florence in 2018 and a tropical connection to Hurricane Joaquin in October 2015), southeast Louisiana and southern Mississippi from a tropical disturbance (August 2016), and most notably over Texas and Louisiana associated with Hurricane Harvey (August 2017), this appears to be materializing.

## 7. REFERENCES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