

# WESTERN REGION TECHNICAL ATTACHMENT NO. 98-01 JANUARY 13, 1998

# A RECORD RAINFALL EVENT OVER THE SAN FRANCISCO BAY AREA AUGUST 1997

## Richard Canepa - NWSFO Monterey, CA Scott Archer - COMET/NWSFO Monterey, CA

## Introduction

On August 19-20, 1997, the remnants of tropical storm Ignacio produced widespread rain over portions of northern and central California, resulting in a 24 hour rainfall record for the month and the second wettest August monthly rainfall ever at San Francisco. In the city of San Francisco at Duboce Park, a storm total of 0.73 inches fell as the tropical rains moved over the area. The all-time monthly record was set in August 1976 with 0.78 inches. Climate records in San Francisco date back to 1850. In Sacramento, 0.19 inches was measured which is the first time rain has been recorded on this date. Sacramento climate records date back to 1877. Similar synoptic patterns have occurred on 9/11-12/1918, 9/3-11/1959, 9/6-10/1976, 8/30-9/6/1978 (Smith, 1986), yet no storms in August have produced such widespread rain over the Pacific Northwest and northern California.

In addition, a strong El Nino began developing over the tropical Pacific beginning in April 1997. Positive sea surface temperatures, not directly related to El Nino, were observed along the entire West Coast during the month of August. Ignacio's movement over unusually warm waters may have helped the tropical system maintain its strength. This Technical Attachment (TA) will examine the upper-air synoptic patterns that led to the formation and movement of tropical storm Ignacio, Ignacio's transformation from tropical to extratropical cyclone, and how the 10km and 29km Mesoscale Eta models forecast Ignacio.

### The Synoptic Pattern And Formation Of Tropical Storm Ignacio

There was very little day-to-day change in the synoptic pattern throughout the month of August. An unusually strong and persistent 300 mb trough was located over the eastern Pacific Ocean. A sprawling area of high pressure at 500 mb was centered near the Four Corners area of the United States and extended out over the California Baja Peninsula. The flow was southerly to southwesterly over the Baja and southern and central California. In the subtropics, an organized area of convection just west of Cabo San Lucas formed

into a tropical depression by 15Z 17 August 1997. By 21Z, the tropical depression had strengthened and became tropical storm Ignacio, but Ignacio began to weaken as it steadily moved northward over relatively cooler Pacific waters. By 09Z 18 August, Ignacio was downgraded to a tropical depression and continued to weaken as it progressed northward. GOES-9 4km visible imagery (Fig. 1) shows the circulation center, convection, and banding associated with tropical storm Ignacio off the Baja coast. On the 19th, spiral bands of convection pivoted northward over central and northern California, with a widespread area of precipitation associated with warm air advection and positive vorticity advection at 500 mb extending north of the surface low. By 00Z 20 August, the surface low and moisture began interacting with a weak 500 mb trough just off the central California coast (Fig. 2). It appears that the surface low re-developed farther off the coast and a resurgence of convection was evident near the weak upper trough seen in Fig. 2. Buoy 46011 located near the south central coast (34.9N and 120.9W) showed evidence of a surface low moving northward off the coast between 20/02Z-09Z. There was a wind shift from the SSE at 20-30 kts to the NW at 5-10 kts, along with a fairly sharp pressure rise (Fig. 3). The pressure began rising prior to the strongest wind in association with a meso-high that developed over the southern California coast (seen in Fig. 2). The surface low then moved northward over Point Reyes, eventually affecting much of Oregon and Washington.

Although Ignacio never attained hurricane strength, it was able to produce widespread rain over much of California, western Oregon and Washington, unlike similar systems where precipitation was focused over central and southern California. In addition, sea surface temperatures (SST) off the West Coast were as much as 5°F above normal during the month of August (Fig. 4\*). SSTs off the southern California coast were reported as high as 74°F (Ernest Daghir's SST analysis 17 August). This may have helped maintain Ignacio's tropical characteristics.

## Transition From a Tropical to an Extratropical Cyclone

Tropical storm Ignacio developed under an area of high pressure aloft off the coast of Baja as a warm core, tropical system. However, Ignacio eventually interacted with an unseasonably strong upper-level trough off the west coast of the United States and evolved into a cold core, extratropical system. Initially, Ignacio showed the typical characteristics of a tropical cyclone with a fairly deep closed cyclonic circulation from the surface to 500 mb, with decreased cyclonic flow and high pressure above 500 mb (Bluestein, 1993). As Ignacio moved westward, a deep trough (for this time of year) was moving eastward toward the Pacific coast. Ignacio's closed 500 mb circulation eventually opened up and was "kicked" northeastward by the upper-level trough. It is important to note that the surface low associated with the tropical storm was initially under a region of high pressure at 200 mb, and eventually would be under a 200 mb trough.

Ignacio's surface features initially showed little temperature advection and baroclinity, as is typical of a tropical cyclone. As Ignacio began to interact with the upper-level trough, an increase in temperature advection and baroclinity was noted at the surface to 500 mb (see Figs. 5 & 6). Figure 6 clearly indicates that strong warm air advection was present on the

west and northwest side of the circulation, and weak cold air advection was seen on the west side. It was at this time that Ignacio transformed from a warm core tropical cyclone to a cold core extratropical cyclone.

## **Rainfall Rates And Totals**

General rainfall totals ranged from 0.5 to 1.5 inches in the northern San Francisco Bay Area with 0.5 to 2.27 inches farther south along the immediate coastal range. Along the central coast, Three Peaks had a rain rate just over 0.9 inches an hour (Fig. 7), with a 24 hour total of 2.2 inches. The greatest hourly rainfall rate at San Francisco Duboce Park was 0.22 inches between 06 - 07Z 19 August, which surpasses a previous record one hour maximum rainfall rate (for August) of 0.18 inches in August 1951 (Null, 1995). Table 1 includes additional storm totals and one hour significant rainfall rates if available.

LOCATION	STORM TOTALS (INCHES)	SIGNIFICANT 1 HOUR RAIN RATES (INCHES)
San Francisco (Duboce Park)	0.73	0.22
San Jose	0.5	N/A
Boulder Creek	1.30	0.45
Monterey	0.1	N/A
Big Sur	1.4	N/A
Three Peaks	2.2	0.9
St. Helena	1.0	N/A
Cazadero	1.8	N/A
Venado	1.5	0.5

### Model Performance

The 00Z 19 August 10 km mesoscale Eta 33 hour total precipitation forecast predicted widespread amounts from 0.25 - 0.5 inches, and up to 1.69 inches on the east side of the Santa Lucia range near Monterey (Fig. 8). It appears that the model position of moisture and surface features were too far east, therefore over-predicting rainfall over coastal locations of central California. The 00Z 20 August 10 km mesoscale Eta caught the westward displacement of the precipitation and convection, this time moving the heavier

rainfall west and north of the Bay area (Fig. 9). The 29 km mesoscale Eta failed to predict the location and intensity of the tropical low when it transformed from a warm core to cold core system. The model was nearly 5 mb too high with the surface low and 270 km too far southeast of the actual location at the 24 hour forecast valid 970820/03Z (not shown).

### Summary

On August 19-20, 1997, the remnants of tropical storm Ignacio produced record rainfall over portions of northern and central California. Climatology shows that rain is very rare over California during the summer months, so any rain measured at all is unusual. However, given the areal coverage and significant amount of moisture associated with the remnants of Ignacio, 24 hour and 1 hour rainfall records were exceeded at San Francisco. and it was the second wettest August ever recorded. Tropical storm Ignacio developed under a tropical wave propagating around the periphery of an upper-level high just off the coast of Baja. The disturbance then interacted with an unseasonably strong upper-level trough off the West Coast, which provided the energy necessary to transform the tropical storm into an extratropical cyclone. Although Ignacio never attained hurricane strength, it produced widespread rain over much of California, Oregon, and Washington. This event was unique in the fact that, in the month of August, no tropical disturbance in recent history has produced rainfall of this intensity so far north along the West Coast. In addition, sea surface temperatures were as much as 5°F above normal during the month of August. helping to sustain the tropical system longer than normally expected. Although the 00Z 19 August 10 km mesoscale Eta did predict up to 1.69 inches of rain, it failed on the timing and location of precipitation. The model failed to predict the strength and location of the surface low, and therefore missed the north and westward displacement of precipitation. The 00Z 20 August 10 km mesoscale Eta caught the west and northward displacement of the low and associated precipitation, showing improvement over the previous run.

\* Figure 4 - Data from National Marine Fisheries Service West Coast Regional Node: http://cwatchwc.ucsd.edu/elnino/eln97-8.gif

## Acknowledgments

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### References

Bluestein, H.B., 1993: Synoptic-Dynamic Meteorology in Midlatitudes. Volume II, Observations and Theory of Weather Systems., Oxford Univ. Press, New York, pp. 136-144.

Null, Jan, 1995: Climate of San Francisco. NOAA Technical Memorandum NWS WR-126.

Smith, Walter, 1986: The Effects of Eastern North Pacific Tropical Cyclones on the Southwestern United States. NOAA Technical Memorandum NWS WR-197.



**Figure 1** GOES-9 4km vis for 970818/20z



Figure 2 GOES-9 4km vis for 970820/00z, 48 km Eta 500 mb heights (dm), and sea level pressure (mb).



**Figure 3** Time series for Buoy 46011. Air temp (F) and SST(F) on top. Mean sea level pressure (mb) second panel, wind speed/direction and gust third panel, wave height/period in last two panels.



Figure 4 SST anomaly from Coast Watch.



**Figure 5** 970819/03z 29 km Eta 00hr analysis of 1000-500 mb thickness (dm) and 850 mb winds (knots). Notice a lack of temperature advection and baroclinity.



**Figure 6** 970820/03z 29 km Eta 00 hr analysis of 1000-500 mb thickness (dm) and 850 mb wind (knts). Notice increased temperature advection and baroclinity.



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Figure 7 Three Peaks hydrograph from 970819/18z to 970820/12z. Rainrates on left.









970820/03z 10 km Eta 33 hour total precipitation (") valid 970822/12z.