Examination of a Cool-Season Monterey Bay Area Severe Weather Event Using the Weather Event Simulator (WES)

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Introduction

This WES case focused on the dramatic severe convective weather events that occurred in the greater Monterey Bay Region on 20 December 2001. The most significant of these was an upper-F1 intensity tornado that moved through semi-rural land near the city of Watsonville, just inland from the NE corner of Monterey Bay (Figure 1), a few minutes after 0000Z 21 December (4 pm PST 20 December). The thunderstorm cell that produced this tornado also generated severe hail; in addition, at least two other severe hail events occurred that afternoon, both in the immediate vicinity of the city of Monterey. Tornadoes and severe hail only occur very infrequently in coastal central California, but when present can cause significant adverse impacts. The aforementioned tornado resulted in significant property damage, with only serendipitous fortune preventing any physical injuries. At least one of the severe hail events also caused some property damage. It is therefore important for our forecasters to acquire and maintain appropriate situational awareness on those rare occasions when the risk of such events is non-negligible.

Overview of WES Exercise

This WES exercise was a bit unusual in that it involved a weather event that occurred prior to our office's acquisition of WES archiving capabilities. As a result, only radar data were available on WES – and we wouldn't have even had that if it hadn't been for some special effort on the part of the staff at the Radar Operations Center to convert the pertinent portions of the KMUX Archive II data to WES format. The exercise itself consisted of two parts: first, the forecasters were asked to examine a set of hard copy basic synoptic analyses and satellite images from 00Z and 12Z 20 December and then from these identify the "problem of the day" – thus establishing a context of "situational awareness." Only when that was completed did the forecasters do the second part of the exercise, which was to fully examine the radar data for the period 1534Z 20 December 2001 through 0159Z 21 December 2001 and answer the following questions: (1) At what times, and for what locations, would you have had significant concern over the possibility of severe weather (i.e., severe thunderstorms or tornadoes) occurring; and (2) in any of these cases was there enough evidence from the available radar imagery alone to justify the issuance of a Severe Thunderstorm or Tornado Warning (and if so, when and for where would you have issued the warning).

Synoptic Overview

NCEP 500 and 850 mb synoptic analyses for 1200 UTC 20 December 2001 are shown in Figure 2a and 2b. These indicate a nearly vertically-stacked cold-core upper-level low centered just off the northern California coast. Of particular relevance to the severe weather that developed later in the day are the relatively strong winds for such a weather pattern at 850 mb. The corresponding NCEP 1200 UTC surface analysis (Figure 3) indicates the cold front has already moved well inland, while the primary surface low pressure center and associated secondary trough remain offshore. As at the 850 mb level, surface wind speeds are rather strong for such an environment, as evidenced by the 25 knot south-southeasterly wind reported just offshore from San Francisco. IR satellite images for 0000 UTC and 1200 UTC 20 December (Figure 4a and 4b) show that both the upper level and surface circulation centers propagated together towards the central California coast during the intervening 12-hour period. It is the unusual presence of the significant surface low and associated wind field, beneath the cold upper-level low, that resulted in the strong low-level shears associated with the severe convection that occurred later in the day.

Mesoscale Severe Convective Weather

The first documented severe weather event of the day occurred just after noon (PST), when a very strong convective band moved across the Monterey Peninsula. The 2003 UTC 20 December 0.5 degree base reflectivity image from KMUX is shown in Figure 5. The feature of interest is the bowed segment in the lower part of the image, then just moving onshore to the Monterey Peninsula. Although it was at its greatest intensity on radar at about the time of this image, and then subsequently appeared to weaken slightly, it nonetheless produced hail to at least 9/16 inches, with a few unverified reports of hail to 1.0 inches in diameter. Depths of hail on the ground reached several inches, with even deeper drifts piled up on some of the local beaches. There was at least one reliable report of hail going through the windshield of a truck.

The second and most significant of the severe weather events documented this day occurred just after 4:00 pm PST (0000 UTC December 22): the Watsonville upper-F1 intensity tornado. The KMUX base velocity image for 0009 UTC 21 December, almost the exact time the tornado was on the ground, is shown in Figure 6. The remarkable degree to which the associated mesocyclone aloft was captured, at least by west-coast standards for a mountain-top radar, is a consequence of the serendipitous close proximity of this tornadic event to the KMUX radar, only about 20 km away. A WFO damage survey was conducted the next morning, and ascertained the actual path of the tornado itself, shown in Figure 7. For much of its approximately 1.3 mile path it traversed rural and largely undeveloped land, but near both its start and termination it did produce some significant damage. Among other events, it destroyed a commercial greenhouse, in which 3 people were working less than 20 minutes before the tornado occurred. A large mobile home was rolled 360 degrees, various sheds and outbuildings were severely damaged or destroyed, a line of electrical utility poles and associated wiring were knocked down, several Eucalyptus trees in excess of 25 m in height were brought down, and roofs of several homes and other buildings were damaged. The same cell that produced the tornado also brought golf-ball-sized hail.

Discussion

The two key factors that appear to be responsible for such rare but significant cool-season coastal central California severe convective weather events are instability and strong low-level vertical shear. That such events are indeed quite infrequent reflects the rarity with which these two things occur in combination. More commonly, when the shear is strong the environment is then pre-frontal and characterized by neutral or positive static stability. Then, when instability and CAPE do occur in the cold post-frontal air mass, typically lower-tropospheric winds are light and thus low-level shear is small. In the present case, however, the primary surface low and associated cyclonic circulation tracked towards the central California coast along with the cold upper-level low. The combination of quite cold air aloft (500 mb temperatures fell to nearly -29 C in the vicinity of the tornado at 0000 UTC 21 December) with strong low-level cyclonic winds resulted in the presence of appreciable positive CAPES (approximately 250-500 J/kg) with strong low-level shear. With respect to the latter, it should also be noted that local topographic channeling appears to play a role in determining where the combination of low-level directional and speed shear, and CAPE, are maximized. In synoptic situations like the present one, the Watsonville area appears to be such a place, as SE winds blowing down the Salinas Valley (see Figure 1) can there flow under the larger-scale lower-tropospheric southwesterly winds. In comparison to the typical Midwestern severe weather environment, CAPES are usually much smaller and the depth of the strong low-level shear potentially much shallower. But in the case of convection associated with cool season cold-core upper-level lows, the total convective depth itself is much reduced, occurring as it does in an environment characterized by an anomalously low tropopause. But under such circumstances, even convective cells that appear entirely unremarkable on radar can nonetheless produce severe weather. An example of this is provided by the third severe weather event documented on 20 December, which was produced by the cell shown in cross section in Figure 8a and 8b. Despite its shallow depth and unremarkable structure, it brought severe hail (jagged chunks of ice exceeding 1 inch in length) tothe roof the Monterey WFO and the surrounding neighborhood.

Figure 1

Figure 2

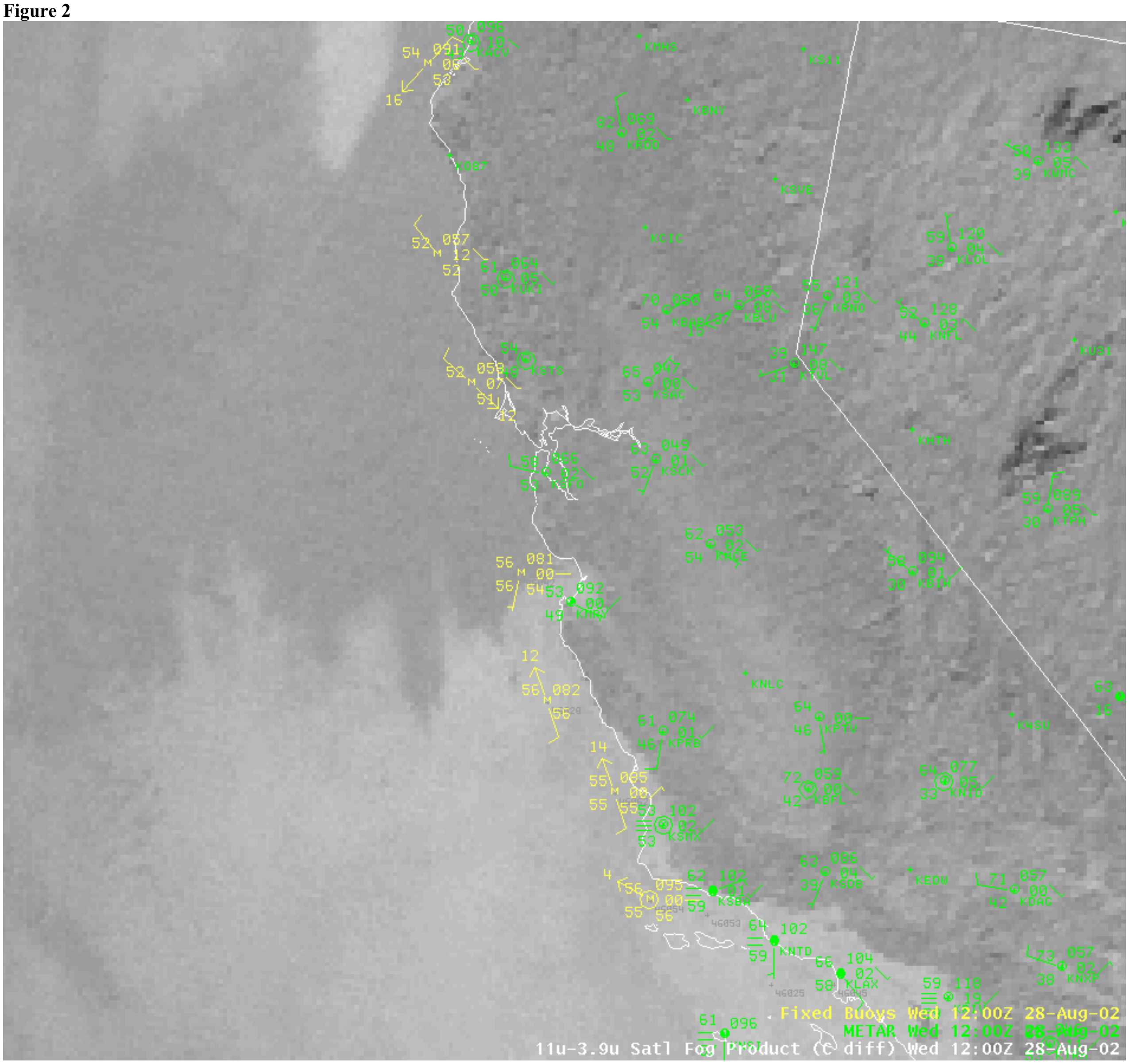


Figure 3

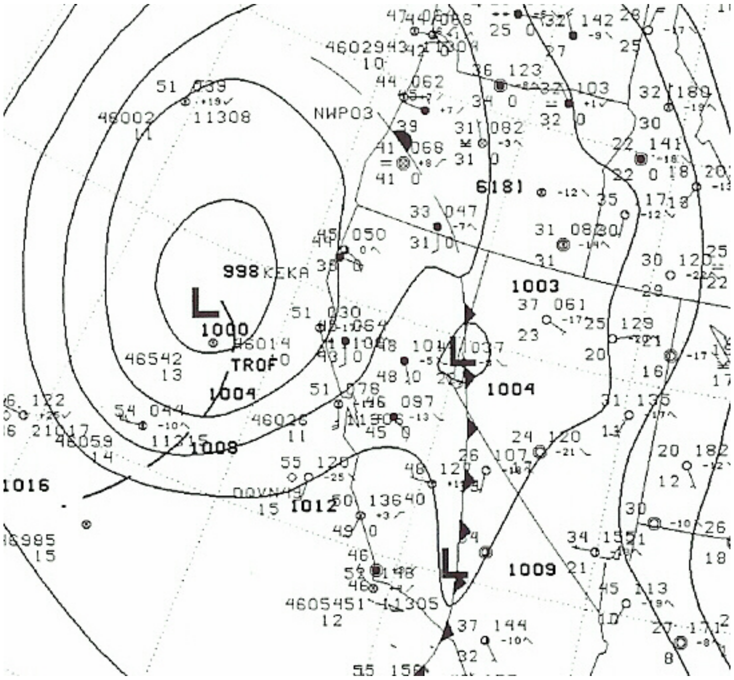


Figure 4a

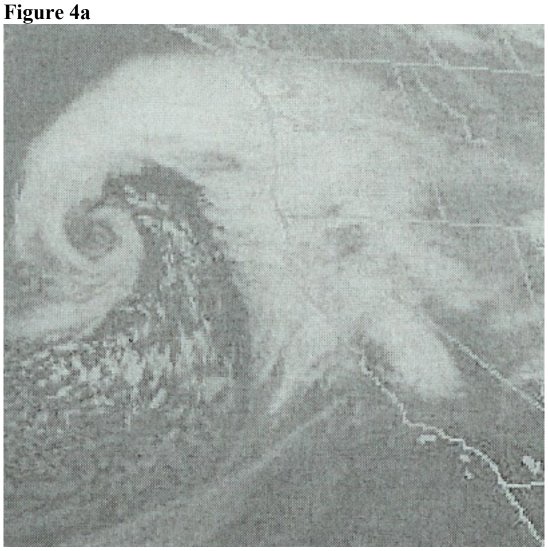


Figure 4b

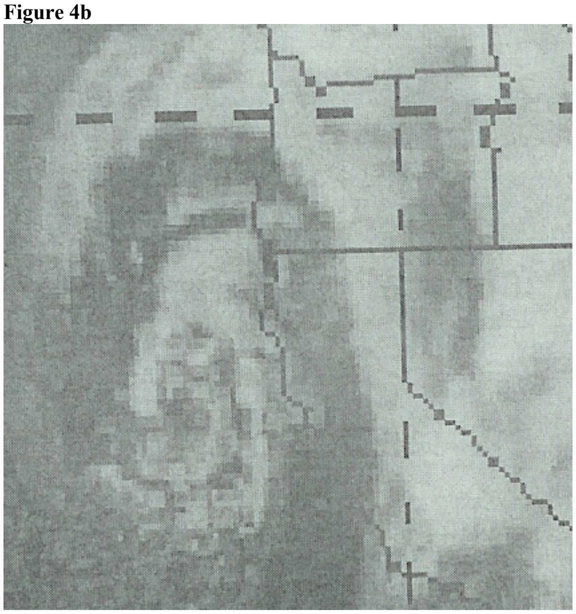


Figure 5

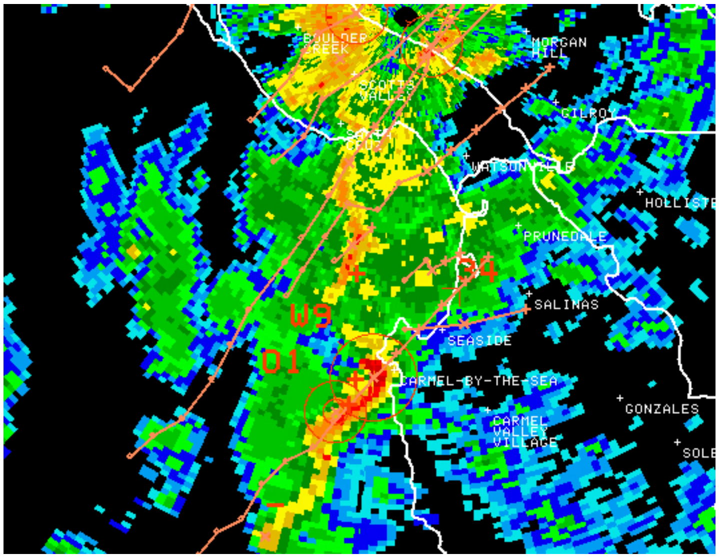


Figure 6

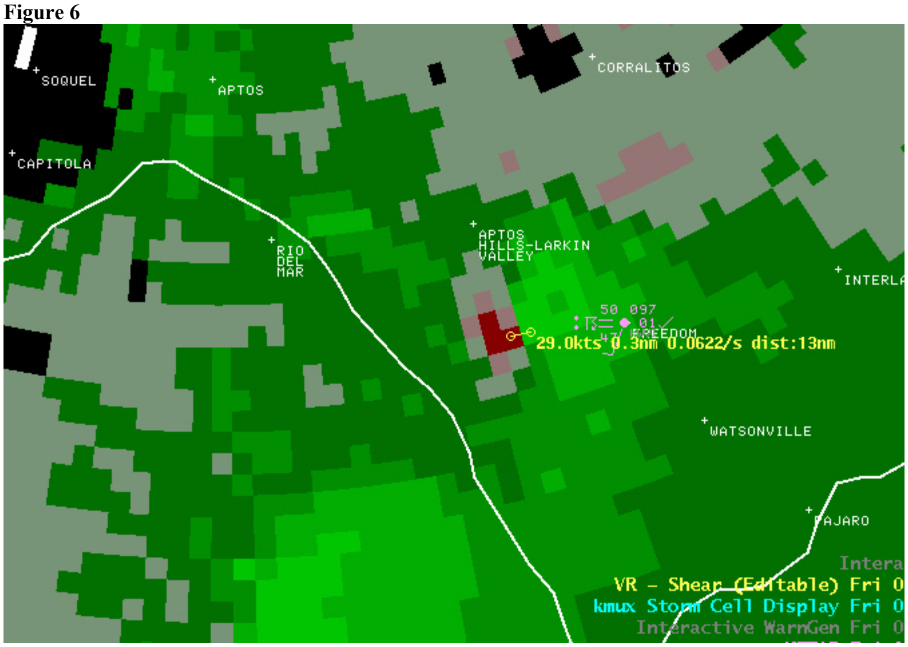
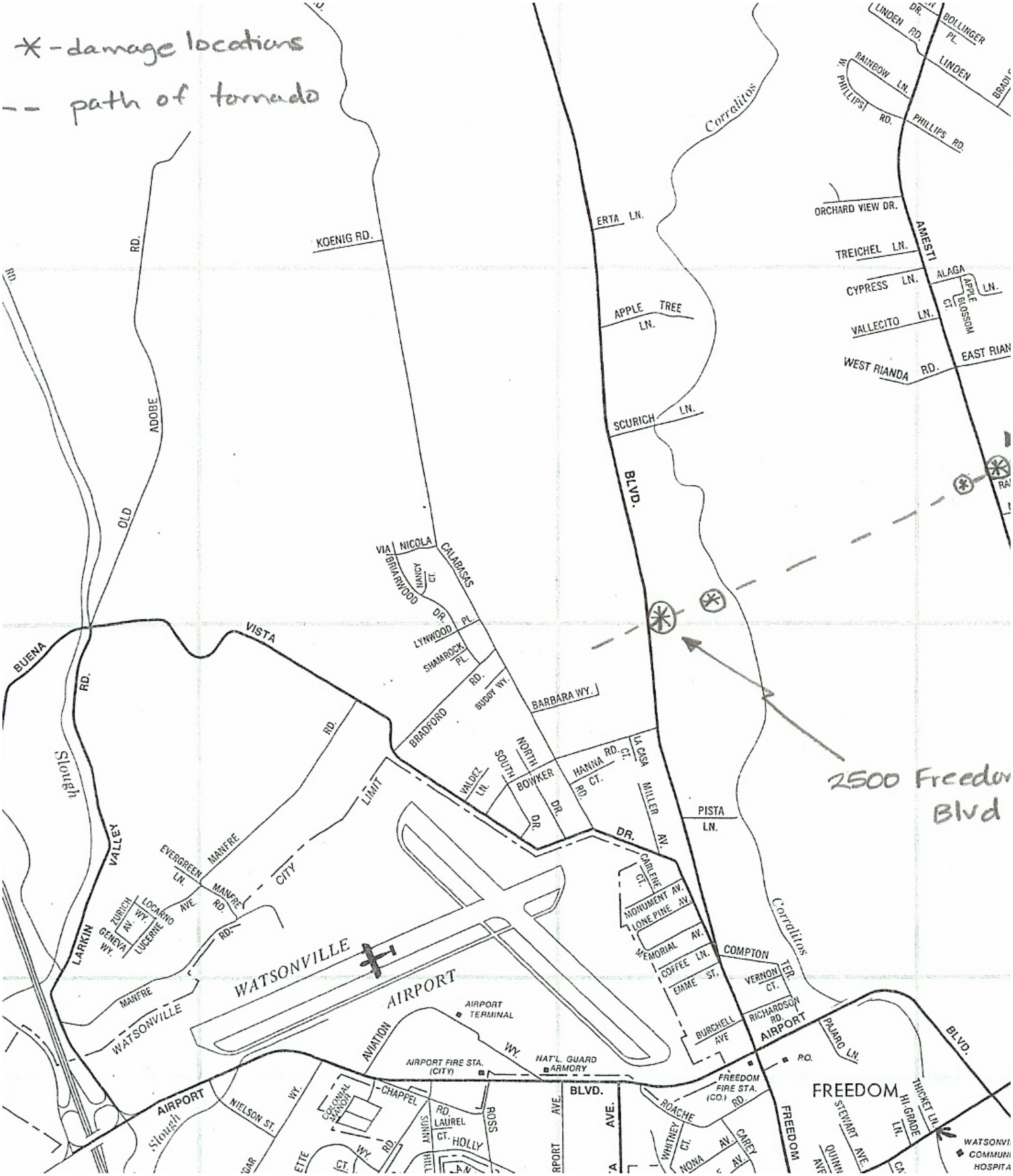


Figure 7



* - damage locations
-- path of tornado
2500 Freedo
Blvd
Corralitos
KOENIG RD.
ERTA LN.
APPLE TREE LN.
SCURICH LN.
BLVD.
ORCHARD VIEW DR.
TREICHEL LN.
AMESTI
CYPRESS LN.
ALAGA
APPLE BLOSSOM CT.
LN.
VALLECITO LN.
WEST RIANDA RD.
LINDEN RD.
BOLLINGER PL.
LINDEN
RAINBOW LN.
W. PHILLIPS RD.
PHILLIPS RD.
OLD ADOBE RD.
RD.
VIA NICOLA
BRIARWOOD DR.
NANCY CT.
CALABASAS
LYNWOOD PL.
SHAMROCK PL.
BUDDY WY.
BRADFORD RD.
BARBARA WY.
BUENA VISTA
RD.
Slough
VALLEY
LARKIN
RD.
CITY LIMIT
NORTH BOWKER DR.
SOUTH DR.
VALDEZ LN.
HANNA RD. CT.
LA CASA CT.
MILLER AV.
PISTA LN.
DR.
EVERGREEN LN.
MANFRE
MANFRE RD.
AVE.
ZURICH AV.
LOCARNO WY.
GENEVA WY.
LUCERNE
RD.
CARLENE CT.
MONUMENT AV.
LONE PINE AV.
MEMORIAL AV.
COFFEE LN.
EMME ST.
COMPTON TER.
VERNON CT.
RICHARDSON RD.
BURCHELL AVE
WATSONVILLE AIRPORT
AIRPORT TERMINAL
MANFRE
WATSONVILLE
AVIATION WY.
AIRPORT FIRE STA. (CITY)
NAT'L. GUARD ARMORY
AIRPORT BLVD.
FREEDOM FIRE STA. (CO.)
P.O.
FREEDOM
PAJARO LN.
BLVD.
THICKET LN.
HI-GRADE LN.
STEWART AVE.
FREEDOM
ROACHE RD.
WHITNEY CT.
NONA
CAREY AV.
AIRPORT
NIELSON ST.
Slough
WY.
COLONIAL MANOR
CHAPPEL RD.
SUNNY
LAUREL CT.
HOLLY
ROSS
AVE.
AVE.
WY.
RD.
CT.

Figure 8a

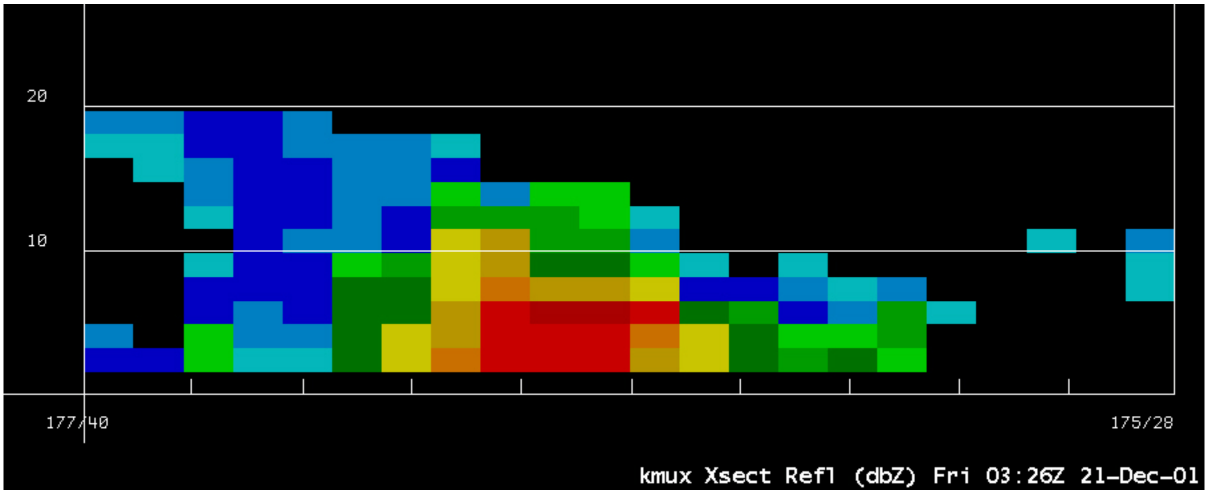


Figure 8b