Western Region Technical Attachment
No. 90-36
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LARGE HAIL IN THE WEST

While small hail is common throughout the higher elevations of the western United States, severe hail (greater than 3/4 inch diameter) is a relatively rare event, particularly in lower valley locations. On September 25, 1990, hail up to 1 1/2 inches in diameter fell over metropolitan Salt Lake City. Since thunderstorms are not rare events in the West, but storms that produce large hail are, it is useful to review the factors that are required to produce large hail. Another large hail event in Salt Lake City that occurred in August 1983, will be briefly compared to the recent event. While both of these events occurred over Utah, the ingredients necessary to produce large hail will apply throughout the Western Region.

The conditions required to produce thunderstorms are fairly well known to most forecasters, although it is frequently difficult to determine when they exist in sufficient combination to produce deep convection. They include:

- instability, based on both lapse rate and moisture availability
- forcing of vertical motion to release the instability, this could be from an upper-level short wave, or it could be due to low-level convergence zones such as colliding outflow boundaries or terrain induced convergence...there are plenty of these everyday in the mountainous West
- stable layer, capping inversion, or dynamic subsidence to allow potential instability to increase at low-levels, to be rapidly released by the above-mentioned forcing...without a stable layer or subsidence, instability may not build up enough to produce deep convection, it may just cloud-up and rain (no thunderstorms)

The above conditions occur frequently during the warm season. What must be added to produce thunderstorms capable of large hail? The basic difference between a garden variety thunderstorm and a hailer is that a hailer has a three-dimensional structure and life cycle such that hailstones can grow large enough to reach the ground when they eventually fall through the lower (warm) layers of the atmosphere. Garden variety thunderstorms typically last about one hour from birth to decay; other storms may continue to form, but individual cells usually come and go in an hour or less. Typically, the updraft forms and the cloud builds until water droplets are big enough to fall out. As the rain falls, a cool downdraft is produced and the updraft is destroyed. Without an updraft to supply warm, moist air, the storm dissipates.

A review of the literature on hailstorms suggests there is still some debate as to the exact mechanism for hail formation, but there is general agreement that the key to a hailer is the coexistence of an updraft and a downdraft (or multiple updrafts and downdrafts) side-by-side within the storm. How does this happen? The storm must be tilted in the vertical to allow the updraft on the inflow side of the storm to continue feeding warm, moist air into the storm, while at the same time, a downdraft and precipitation core produce cool outflow air at the surface. Hailstones grow by being recycled through the updraft and downdraft. Again, there is some debate in the literature as to whether hailstones are recycled, or whether they merely shift about within the strong updraft. Since the updraft is not destroyed by the downdraft, the storm will last longer, and in the case of a supercell thunderstorm, may actually reach a steady state.

The atmospheric conditions that create this type of storm include the usual factors listed above for thunderstorms, but in addition, include vertical wind shear. The wind speed must increase with height to produce a tilted storm. Directional shear is also helpful in creating a long-lived storm, and can add the possibility of storm rotation. However, directional shear is not as important a requirement as is vertical speed shear for hail. Recent research points out the importance of the storm relative shear profile (helicity) rather than ground relative wind shear for severe storms and tornadoes, but that is beyond the scope of this discussion.

The thunderstorm season over the West usually coincides with weak upper-level flow. This is particularly true when the Arizona monsoon is active. There is typically sufficient low-level moisture to provide significant instability capable of producing deep convection, but the flow aloft is quite weak. The transition out of the monsoon as the westerlies drop southward is frequently a time for hailstorms in the southwest part of the United States. This situation may be a temporary interruption in the monsoon due to an unseasonal trough during July/August, or it could be in the fall as the mean westerly flow drops south. Across the northern portions of the West, vertical wind shear is more common throughout the warm season, but particularly in June and early July and again in September, when strong synoptic-scale systems are moving through the area.

A few maps and soundings from the September 25, 1990 and August 21, 1983 Salt Lake City hailstorms are presented. In both cases, the large hail occurred near mid-afternoon. In the 1983 event, there was very strong dynamic forcing associated with an unseasonably strong jet over the area. The 1990 event was also dynamically forced, but the jet was not over the area. Although the jet was not over Utah in the recent case, there was still considerable vertical wind shear. The 1983 case exhibits even stronger shear, and, in fact, this event produced very widespread hail of 1 1/4 inches in diameter and considerable property damage, while the 1990 event was less extensive and did less damage. The key ingredients were present in both cases: instability due to steep lapse rates and low/mid-level moisture, a stable layer (and probably dynamic subsidence), a forcing mechanism to help release the potential instability, and vertical wind shear to produce long-lived, tilted thunderstorms capable of producing large hail.

A special thanks to Ken Labas of the Salt Lake City WSFO who wrote up the 1983 hailstorm as an on-station Picture of the Month.

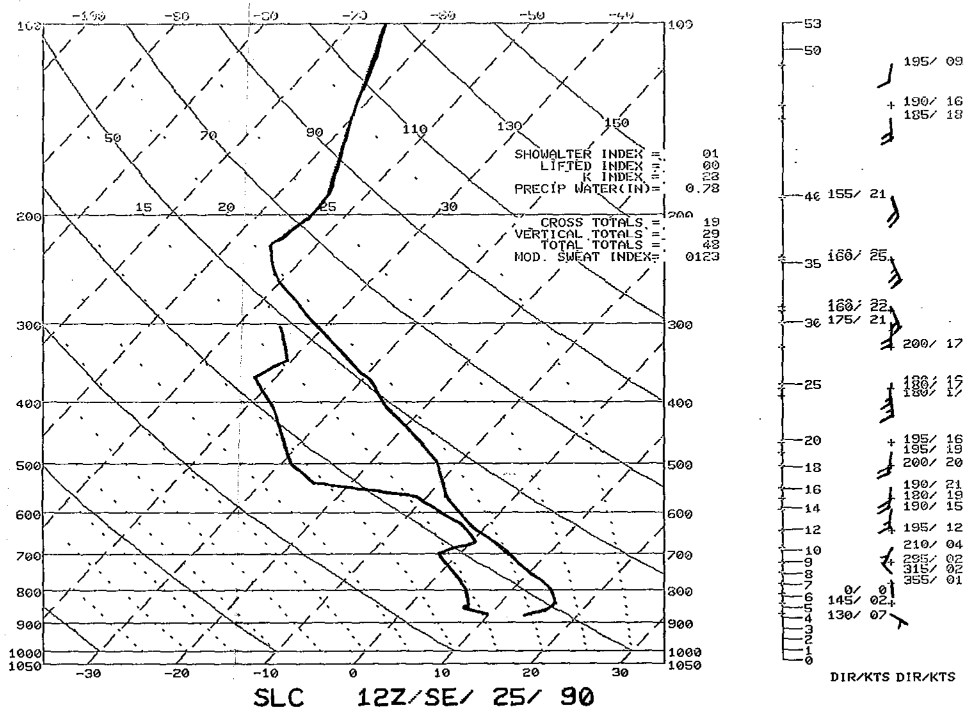

Figure 1A.

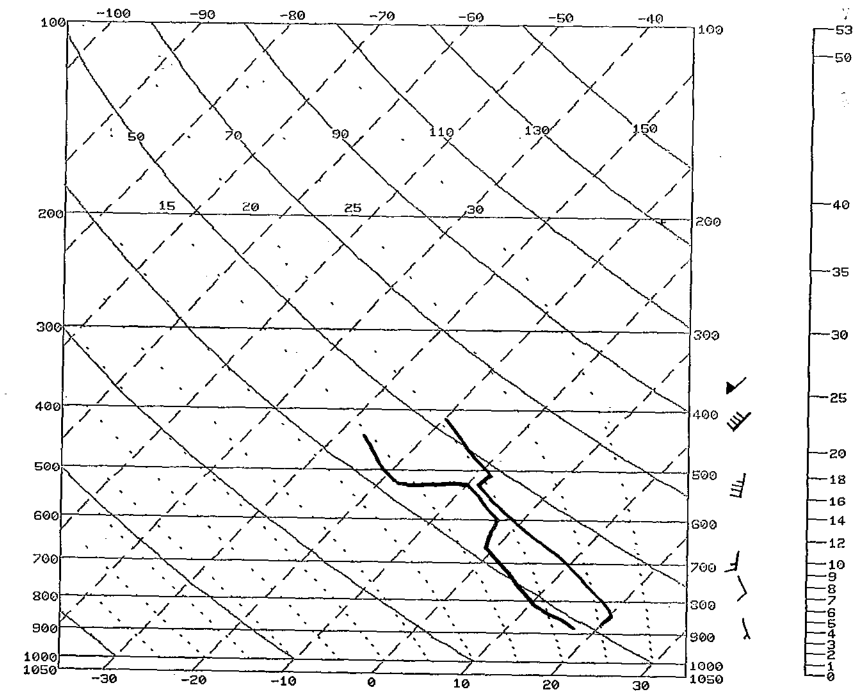

Figure 1B. SLC 12Z Aug 21, 1983

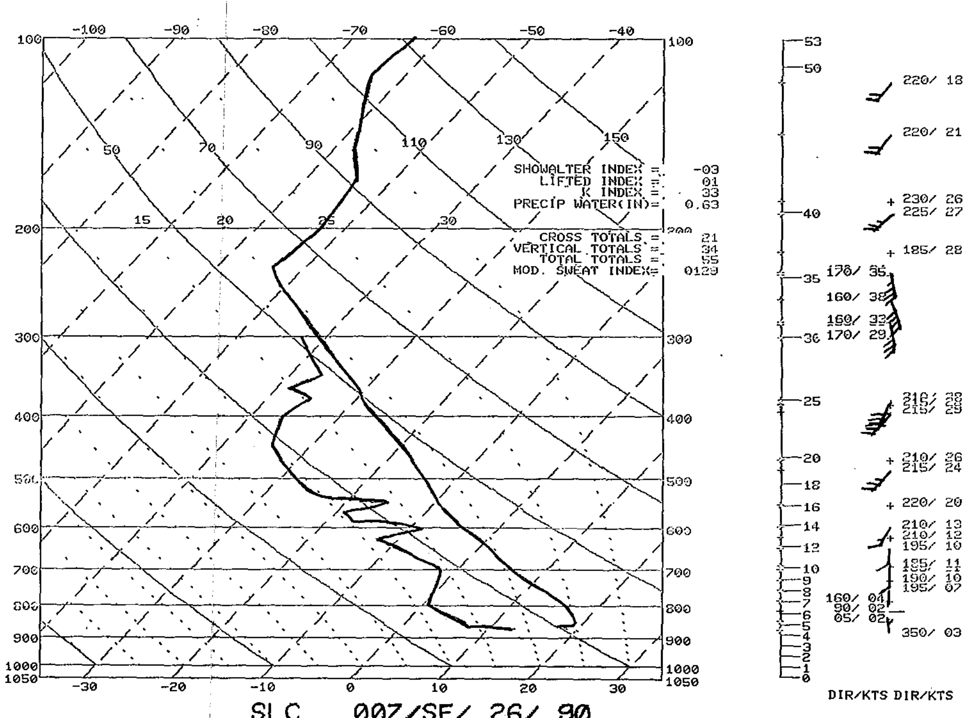

Figure 1C.

Figure 1. The soundings from a) 12Z 25 SEP 1990, and b) 12Z 21 AUG 1983, and c) 00Z 26 SEP 1990. These soundings are quite different, but notice the 12Z soundings both have stable layers between 500 and 600 mb to cap convection and there is vertical wind shear in the 00Z 1990 and 12Z 1983 soundings.

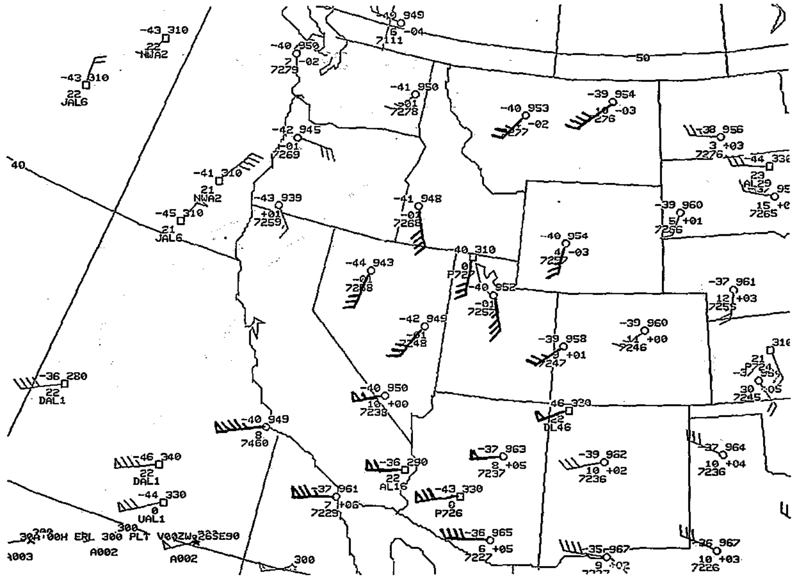

Figure 2A.

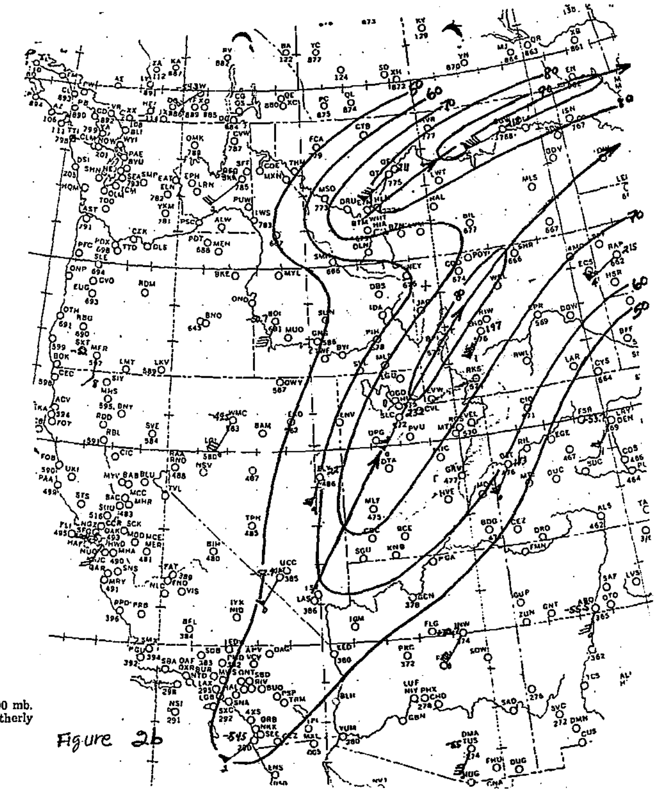

Figure 2b

Figure 2. The 00Z data from a) 26 SEP 1990 - 300 mb, and b) 22 AUG 1983 - 200 mb. Again, there is considerable difference, although both exhibit relatively strong southerly flow.

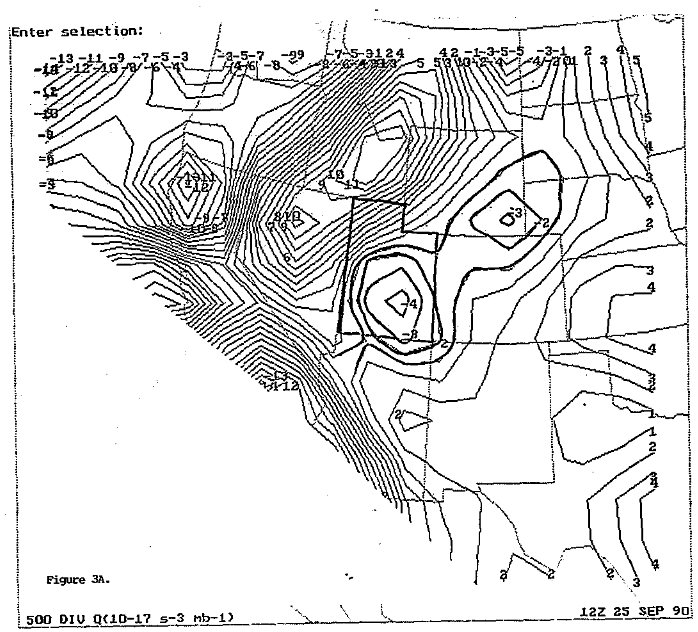

Figure 3A.

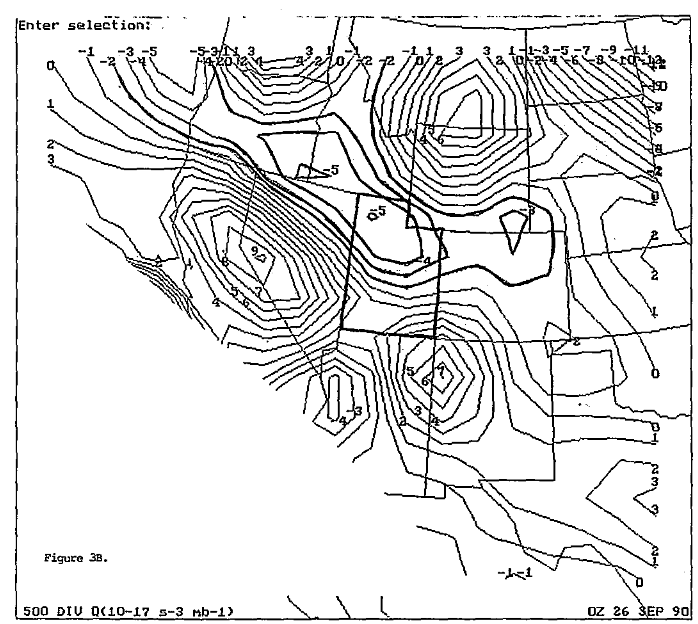

Figure 3B.

Figure 3. The 500 mb Divergence of Q for a) 12Z 25 SEP 1990 and b) 00Z 26 SEP 1990. The area of convergence of Q over northern Utah and southern Idaho in the 00Z analysis indicates forcing for upward vertical motion.