Western Region Technical Attachment
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DEVASTATING ARCTIC OUTBREAK IN THE SACRAMENTO VALLEY

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Background

A frigid arctic air mass, originating in Northwestern Canada, rolled into northern California on December 20, 1990. Several days of record breaking cold temperatures destroyed the citrus crop in the northern Sacramento Valley, and only about 25 percent of the crop had been harvested.

Commercial citrus orchards are located on the west side of the valley around Orland and in the Sierra Nevada foothills in the vicinity of Oroville. Temperatures under 28 degrees can cause damage to citrus fruit, and readings under 25 degrees for any duration can be damaging. On the morning of December 20, following an afternoon of snow showers to the valley floor, temperatures plummeted to the upper teens in the Oroville area and around 24 degrees in Orland. Growers in Oroville lost most of their crop on this morning. Growers in Orland were able to salvage much of their crop using irrigation protection to effectively raise the dew point temperature.

On the morning of December 21, northerly winds developed behind an arctic front with cold air advection, and the mercury plummeted to between 16 and 20 degrees throughout the district. High temperatures broke cold weather records on December 21 with readings only climbing to around 30 degrees. All-time, record-breaking cold temperatures occurred on the morning of December 22, along the east side of the valley. Chico was 10 degrees, eclipsing the old record of 11 degrees set in December 1932. Temperatures were reported as low as 8 degrees, and many residents suffered with frozen and broken water pipes. Northerly wind had decreased on the east side of the Sacramento Valley, allowing for maximum radiational cooling. On the west side of the valley, in the citrus district, north wind continued through the night and temperatures only dropped to the upper teens.

On December 23, cold air drainage off the foothills and into the valley was not confined to the east side. With light wind, cold air spread across the valley and temperatures plunged to record lows on the west side with readings down to 14 degrees at Orland. This unprecedented cold assured little hope for salvaging citrus fruit, even for juice. Oranges were as hard as softballs and had a bitter taste.

The follow-on concern is the state of the citrus trees. Many trees showed cold weather stress with leaf curl and some leaf drop. It is still too early to determine how extensive the freeze damage was. In addition, other trees and crops are susceptible to damage when temperatures fall to the lower teens.

Synoptic Pattern

The freeze was associated with a deep cold upper trough which settled over the far western states over a period of several days. The trough was spawned by strong northerly jet stream winds which advected dry arctic air from northwestern Canada.

On the morning of December 20, an arctic front had crossed the mountains of extreme northern California and moved into central California (figure 1). The morning sounding from Medford (figure 2a) revealed an arctic air mass to around 7,000 feet while the Oakland sounding (figure 2b) only showed a deep continental polar air mass to around 12,000 feet. A west-to-east oriented short-wave trough was rotating around the back side of the upper low and was evident at 700 mb on the 00 UTC 21 December analysis (figure 3). This impulse was the mechanism for the cold advective freeze on the morning of the 21st with brisk north wind in the valley. The short wave was still present on the 1200 UTC 21 December 700 mb chart (figure 4), and eventually drove the arctic front southward beyond central California.

On the morning of December 22, a large gradient in temperature across the valley was observed, with minimums near 10 in Chico and 20 degrees in Orland. This gradient is not unusual and is characteristic of surface high pressure moving into the Great Basin (figure 5) and warm advection above the boundary layer. The warm advection makes inversion development more favorable, and the pressure gradient shifting to northeasterly often steers surface flow away from the eastern foothills. If downvalley pressure gradients remain strong, north winds will persist along the west side of the valley through the night.

The 00 UTC surface analysis for December 23, (figure 6) indicated the movement of the surface high further south through the Great Basin and more of an easterly gradient for the Sacramento Valley. The isallobaric analysis in figure 6 indicates the most significant pressure falls at the north end of the valley, often signifying the end of the north wind pattern. When the wind diminishes, the thermal gradient across the valley decreases significantly.

The passage of an arctic front through much of the state is a rare occurrence. Dew point temperatures behind the arctic front were in the single digits with readings below zero when the north wind was strong.

Forecasters need to be aware of meteorological parameters necessary to produce such record cold weather. The study by Ron Hamilton, The Worst Winter Ever, points out several ingredients related to damaging cold in the agricultural districts of California. In this event, several of these ingredients and others were present...

1) Very cold temperatures through a deep layer of the atmosphere. 850 mb temps= -10°C (figure 7a) and 500 mb temps=-35°C (figure 7b) with 1000-500 mb thickness under 5200 meters;

2) Strong and deep cold advection with daytime surface temperatures climbing to 40 degrees or lower;

3) Air mass originating in the arctic;

4) Rapid transport of the arctic air mass southward by a strong northerly jet stream (>100 kts), avoiding significant modification of the air mass (figure 8);

5) Strong surface low pressure development over the eastern Great Basin ahead of the arctic air mass;

6) Strong surface high pressure from Canada translating into the Pacific Northwest and Great Basin behind the arctic front;

7) Cold upper low into eastern Oregon and northern Nevada with heights under 5300 meters.

Other noteworthy factors that contributed to the severity of the freeze were the short length of the nights, lack of direct insolation during the daytime, and consecutive nights of critical temperatures with little warming effect from the wind.

Conclusion

NMC models did a commendable job forecasting this event with about 72 hours lead time. Growers were notified through agricultural forecasts and special statements at least two days in advance that record-breaking cold was headed for the Sacramento Valley. The lead time did allow for an increased pace of harvesting, but little could be done in the way of freeze protection in this case.

In future events, forecasters should be alert to the above meteorological parameters and attempt to provide as much lead time as possible on a severe cold weather event. The agricultural community pays close attention to our forecasts, especially when potentially damaging weather is forecast.

Reference

Hamilton, Ron: The Worst Winter Ever: Part I and II, Citrograph Magazine.

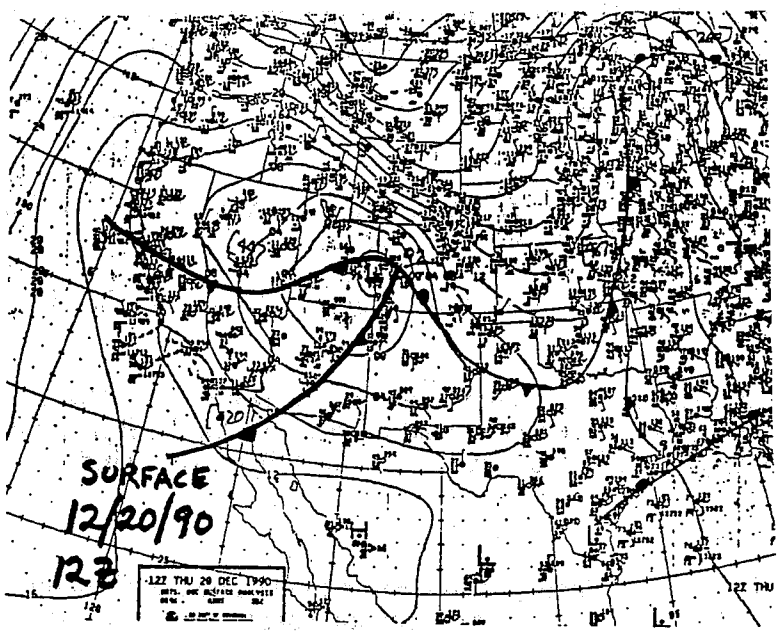

Figure 1. Sea Level Pressure 12 UTC 20 Dec. 1990

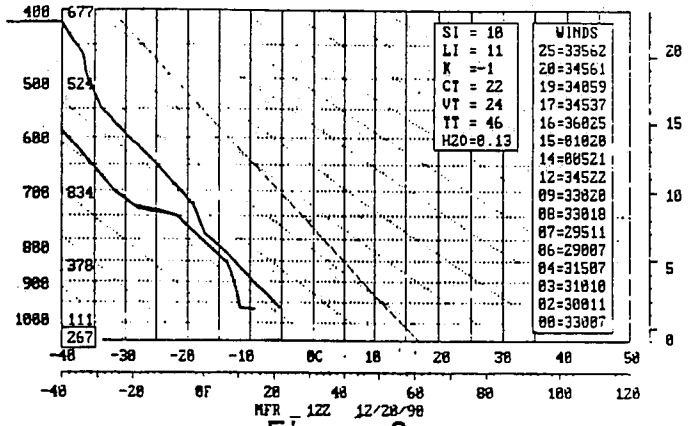

Figure 2a

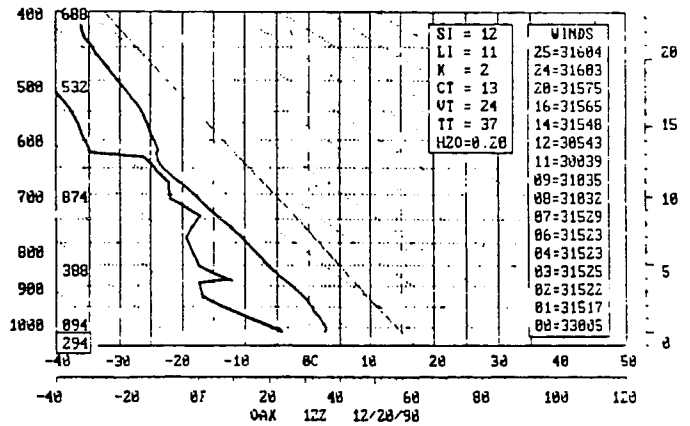

Figure 2b

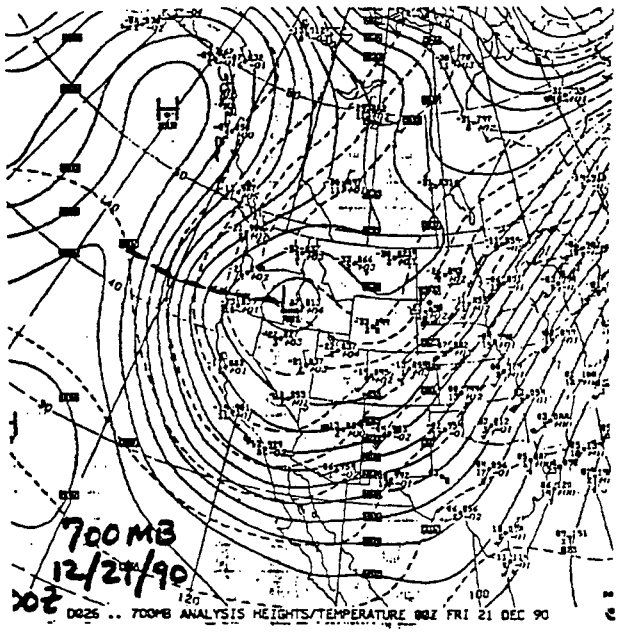

Figure 3

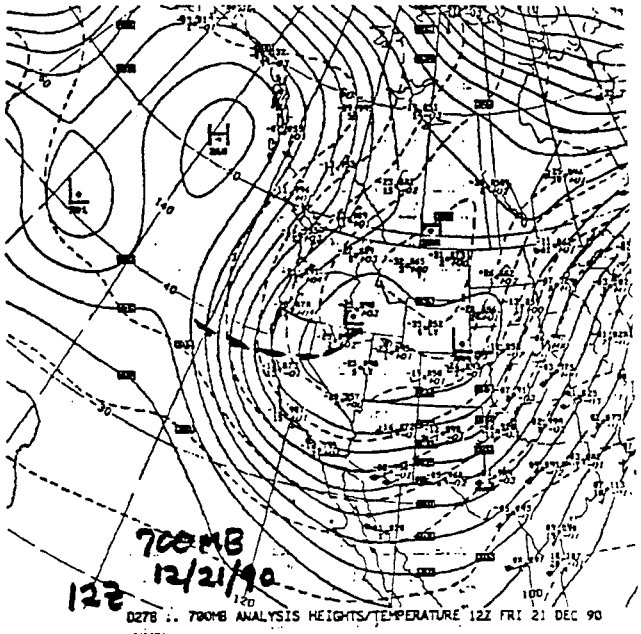

Figure 4

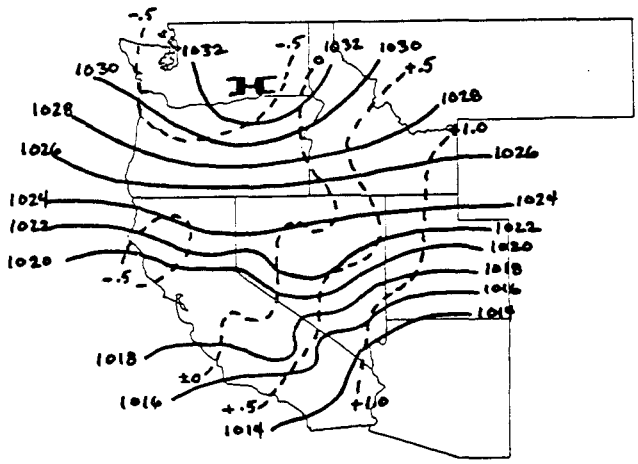

Figure 5. Sea Level Pressure (solid lines) and Isallobars (dashed lines) for 00 UTC 22 Dec. 1990

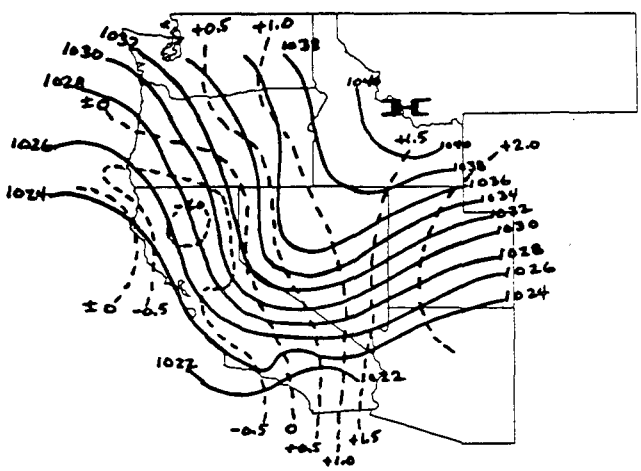

Figure 6. Sea Level Pressure (solid lines) and Isallobars (dashed lines) for 00 UTC 23 Dec. 1990

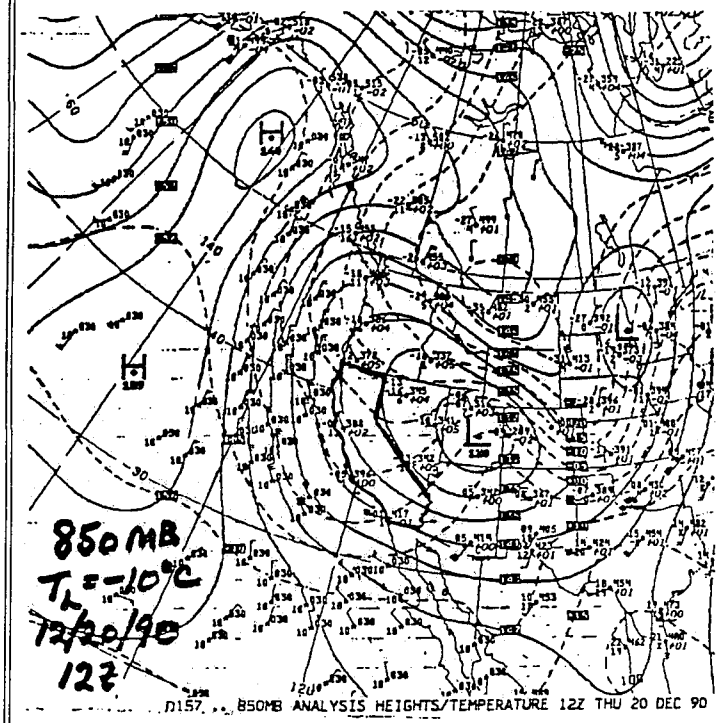

Figure 7a.

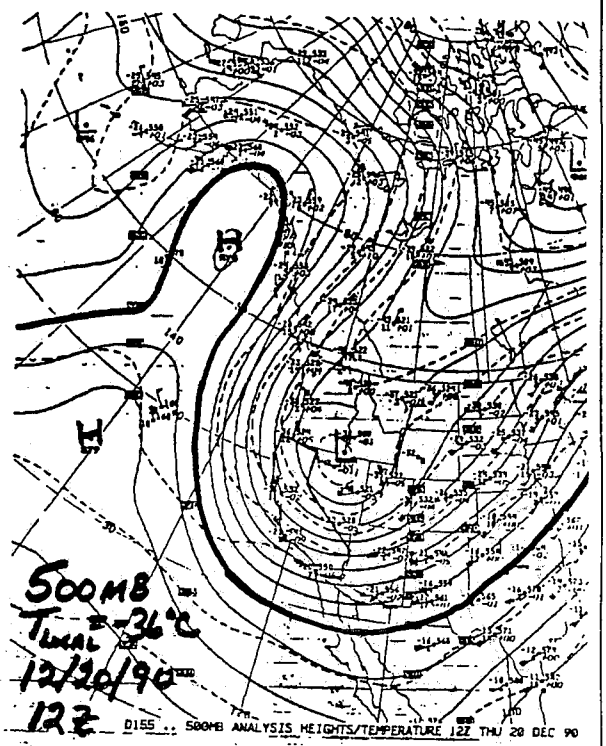

Figure 7b

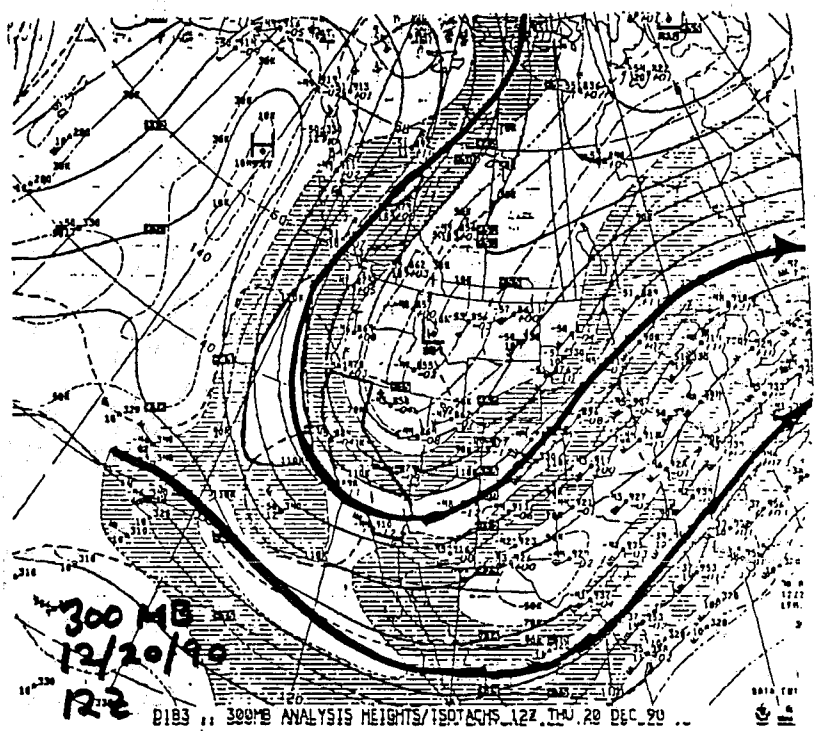

Figure 8