Effect of surrounding terrain on

Spring Temperature Inversions

in the Sacramento fruit-frost district

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Temperature inversion, probably the most important meteorological factor in frost protection in the Sacramento Valley fruit producing area, is under continuing study initiated in 1956.

Temperature inversion means that the night temperature of the atmosphere rises with increased height when radiational cooling of the ground cools the air adjacent to it. The depth of the layer of air in which a temperature inversion is present is called the inversion layer. The inversion layer is stable, with little turbulence, and may vary in thickness from a few feet to several hundred feet. The strength of the inversion—the rate of increase of temperature with height—is dependent on the soil properties, type of vegetation, length of the night, cloud conditions, wind speed, and other variables, but its strength and depth are important in frost protection practices. With a strong inversion, a wind machine has more relatively warm air to mix with the colder air next to the crop and the stronger the inversion the more the hot gases from orchard heaters are prevented from rising too high above the ground.

A knowledge of typical inversion conditions, during frost season, is desirable for planning frost protection systems. One result of a lack of this information has been that many wind machines have been installed in the Sacramento Valley area on the basis of results in a region

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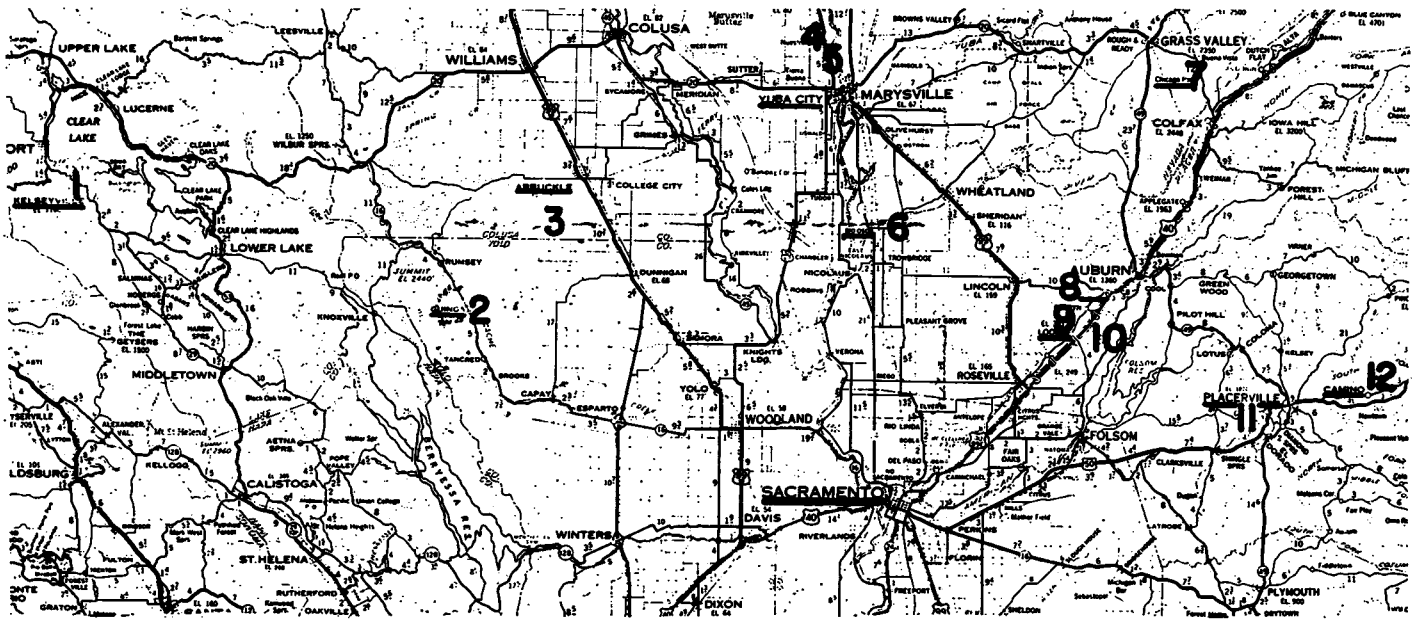

Locations of temperature measuring instruments for study of spring inversions in the Sacramento fruit-frost district.

1. Pear orchard northwest of Kelseyville. Elevation: 1,150'. Period of record: March 23, 1956–May 10, 1956.

2. Grass covered field in the center of the town of Guinda with the surrounding land in almond orchards. Elevation: 355'. Period of record: February 1, 1960–May 4, 1960.

3. An almond orchard five miles southwest of Arbuckle. Elevation: 170'. Period of record: February 23, 1956–April 30, 1956.

4. An almond orchard four miles north northwest of Yuba City. Elevation: 65'. Period of record: March 1, 1956–May 10, 1956; February 6, 1958–May 15, 1958; February 6, 1959–May 15, 1959 and February 1, 1960–May 15, 1960.

5. A prune orchard 3½ miles north of Yuba City on the west side of the Feather River. Elevation: 60'. Period of record: February 28, 1956–May 10, 1956.

6. A peach orchard one mile southwest of Four Corners between Rio Oso and Wheatland. Elevation: 55'. Period of record: February 1, 1959–May 15, 1959 and February 1, 1960–May 15, 1960.

7. A pear orchard one-half mile west northwest of Chicago Park. Elevation: 2,313'. Period of record: February 1, 1960–May 31, 1960.

8. Over grass in a slight draw in a plum orchard half way between Lincoln and Newcastle. Elevation: 400'. Period of record: February 1, 1960–May 31, 1960.

9. A pear orchard 1½ miles northwest of Loomis. Elevation: 365'. Period of record: March 20, 1956–April 30, 1956.

10. A peach orchard 3½ miles east of Loomis. Elevation: 620'. Period of record: March 12, 1957– May 13, 1957; February 26, 1958–April 30, 1958 and February 1, 1959–April 28, 1959.

11. A pear orchard 3½ miles southwest of Placerville. Elevation: 1,560'. Period of record: February 13, 1960–May 31, 1960.

12. A pear orchard two miles northeast of Camino. Elevation: 3,300'. Period of record: February 13, 1960–May 31, 1960.

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of stronger inversions, as in the citrus districts of southern California.

In the spring of 1956 instruments were installed, at several locations in the Sacramento Valley, to measure the strength of the temperature inversion between 5′ and 50′ above the ground. Five feet is a convenient height in the tree zone and 50′ is at about the top of that portion of the inversion layer affected by frost protection practices. Due to mechanical difficulties the highest temperature instrument at Kelseyville was at 34′ and at Chicago Park it was at 44′ above the ground. For purposes of this study the inversion strength is defined as the high temperature less that at 5′. Since 1956, records have been collected for a variety of locations and for varying lengths of time. In 1960 the program was intensified in cooperation with the United States Weather Bureau. The period of time for which there is inversion data is short for a climatological study but the data are useful for current planning of frost protection systems.

Instruments to measure the strength of temperature inversions were installed at the locations shown in the illustration on page 7.

The stations near Yuba City, Arbuckle, and Rio Oso are on the relatively flat valley floor; the Guinda station is in the open on the floor of the Capay Valley, and the rest of the stations are in the mixed-up terrain of the foothills.

Inversion Strength

The observations of minimum temperatures were reported daily to the United States Weather Bureau in Sacramento during the 1959 and 1960 spring frost seasons, to be used as an aid in the preparation of the frost forecasts. While useful as a guide, these temperatures do not give a true picture of the inversion strength because the minimum temperatures at the two heights may not occur simultaneously. To pick conditions typical of potential frost damage, the recorded data were analyzed to determine an hour's average inversion strength during those hours when the five-foot temperature was equal to, or less than, 35°F.

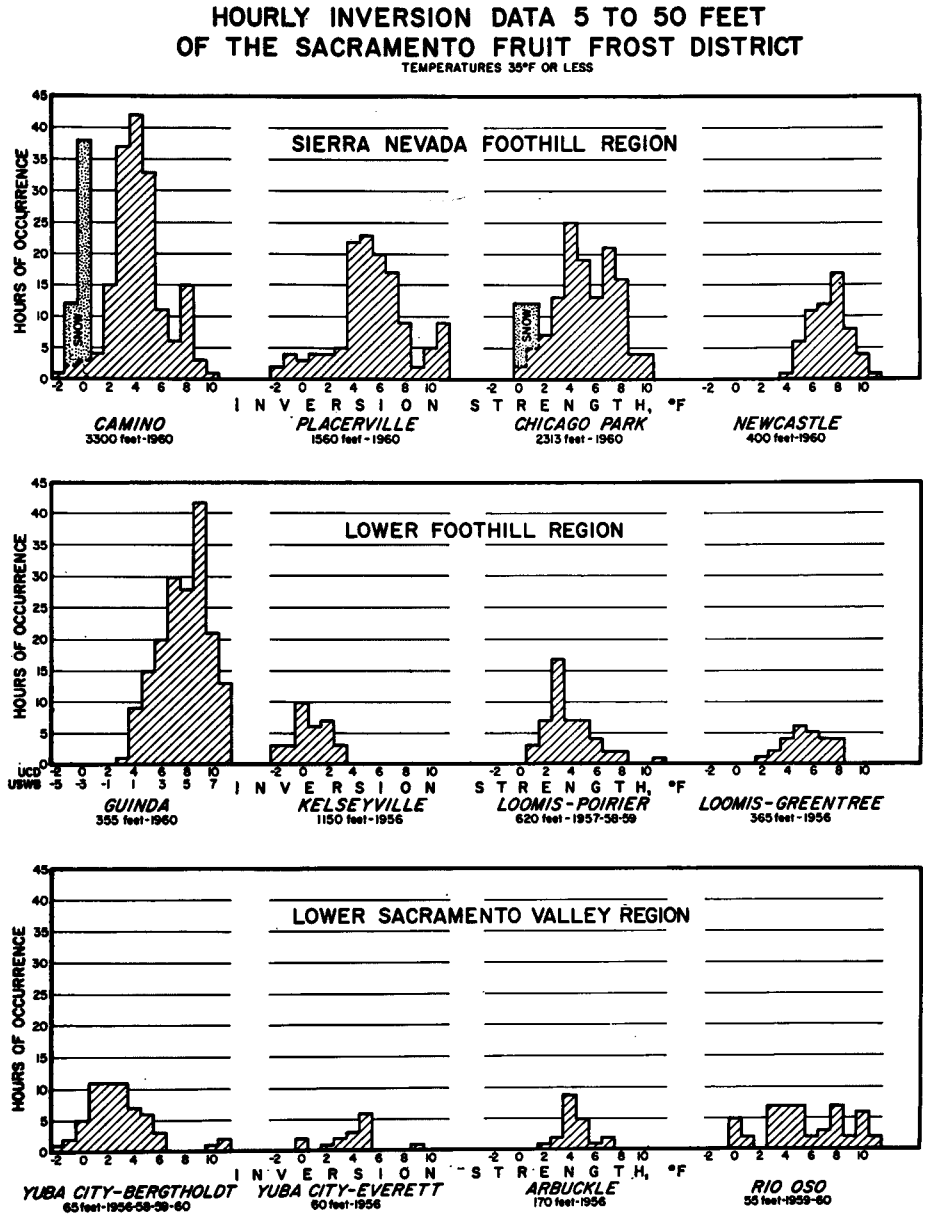
The graphs on this page give the total number of hours that an inversion of the specified strength occurred. Those locations with data on more than one frost season have more hours of inversion data on the graphs but the most frequently occurring inversion strength, and its variations, are shown. The longer the period of record, the more meaningful the data because there is no assurance that any one year represents the average conditions.

Two scales for the inversion strength were computed for the Guinda location: one from temperature measurements at 5′, immediately adjacent to the 50′ mast, and the other from measurements made by equipment on ground about 3′ higher and 50′ to the northeast. The first temperature measurement was colder because of the slightly lower elevation and a better ventilated shelter and gives the true inversion at that particular location, but the growers in the area believe the temperature inversion computed from the measurements at the higher location to be more typical of the surrounding orchards.

To aid in the interpretation of the temperature inversion data, wind data for the same periods of time were analyzed for five locations. With the exception of Loomis, there was no particular association of wind speed with a specific direction.

Effect of Topography

Guinda, located in the bottom of the relatively long, narrow Capay Valley, on the east side of the coast range, is a good example of the effect of topography on minimum temperatures. Cold air drains off the adjacent hills to collect on the valley floor and being on the east side of the coast range it starts cooling sooner



Temperature inversion strength typical of potential frost damage situations.

in the evening and is more protected from the normal westerly winds than the west side of the Sierra.

Wind records at Guinda indicate that calm conditions are the dominant situation when the 5′ temperatures are 35°F or less. Only occasionally does the cold air move downhill to the southeast along the axis of the valley floor, and then, the flow is so weak there is very little turbulent mixing of the lower air layers. These circumstances combine to make Guinda one of the coldest locations and one with the strongest inversions.

A similar situation occurs at Newcastle and Placerville, where the recording instruments were located at slightly lower elevations than the surrounding foothill terrain. Cold air tended to drain into the instrument area and the general flow downhill along the main axis of the nearby creek beds was too slow to cause any appreciable mixing.

At Loomis, the instruments were located in a peach orchard that sloped slightly downhill to the south. Cold air tended to drain into the area but a sufficiently strong flow of air occurred from the east and northeast to cause turbulent mixing of the lower layers. The turbulence decreased the inversion strength and raised the lower temperatures. The source of cold air to cause this strong flow is evidently an 80′ hill 800′ to the east northeast and covered with young citrus trees. The flow of cold air was repeated with marked regularity and is associated with the higher wind speeds reported for this orchard.

Valley Locations

The locations in the foothills generally have more hours of colder temperatures than the valley locations. Four seasons of data from an orchard at Yuba City do not show as many hours of cold temperatures as some of the higher foothill locations show for the 1960 season. Also, the inversions are weaker in the Sacramento Valley where the locations are exposed to the general wind currents of the valley and it is seldom calm long enough for a strong inversion to develop.

The two years of wind data from the orchard near Rio Oso show the great variability of wind speeds and wind direction which, probably, is typical of most of the locations on the Sacramento Valley floor. Although there is a predominance of northerly winds on cold nights, the variability is sufficiently large to justify rejection of a frost protection system dependent on a specific wind direction. At the Rio Oso location, a variety of wind directions can occur in a single night.

The studies have revealed that the average inversion strength for the Sacramento Valley is about 3°F to 5°F and the wind patterns appear to be rather erratic on cold nights. Inversions are stronger in some of the sheltered foothill regions but this is greatly influenced by the particular topography of each location, the resulting nocturnal winds and the longer durations of temperatures of 35°F or less.

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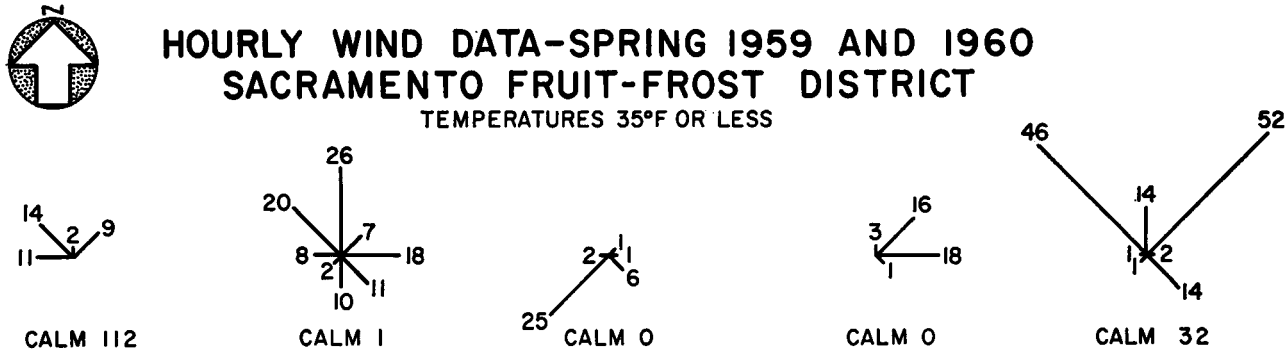
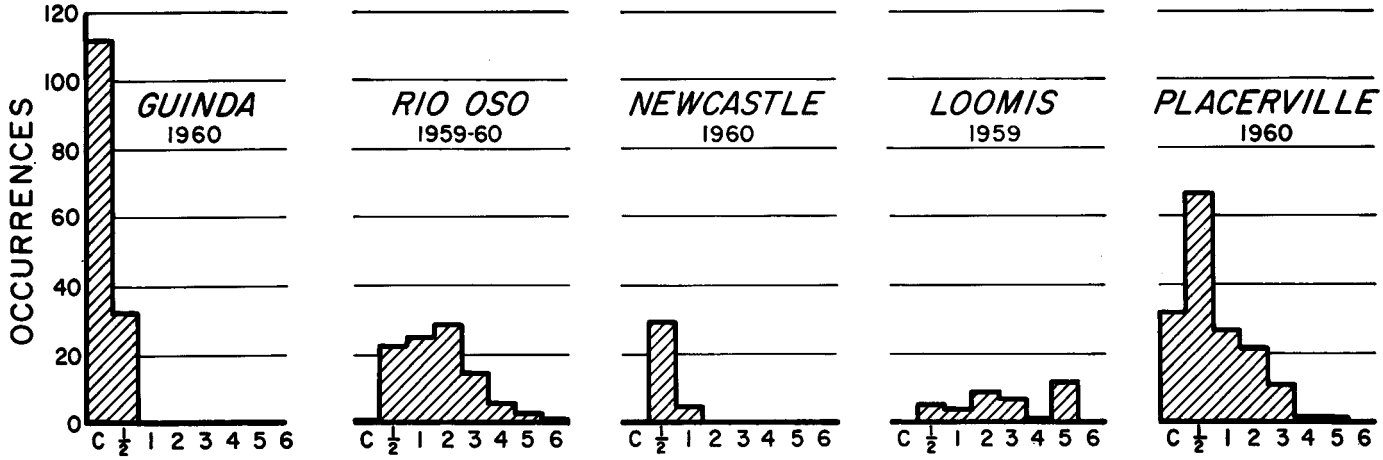
Data for the above reported study were collected by growers in whose orchards the measuring instruments were located, by Farm Advisors in those counties, and by personnel of the Agricultural Engineering Department, University of California, Davis.



Spokes of the wind roses indicate the number of hours that the wind was from the given direction.



Wind speed—miles per hour.