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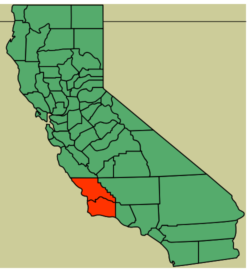
University of California Cooperative Extension

Grape Notes

San Luis Obispo & Santa Barbara Counties



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The April 2011 Central Coast frost event

Inland vineyard areas on the Central Coast were struck by a severe frost in early April 2011. This article summarizes the mechanics of this frost event and how site management affected frost damage outcomes. Note that this article reflects additional damage information received since the first version was written on 4/20/11.

A severe frost occurred on the mornings of April 8 and 9, 2011 on the Central Coast. This frost affected vineyard regions in the inland areas most severely (Paso Robles, Santa Ynez Valley), with relatively less damage in the low elevation vineyards of the more coastal regions (Edna Valley, Arroyo Grande Valley, Santa Maria Valley, Los Alamos Valley, Sta. Rita Hills). However, some high elevation vineyards in the coastal areas were heavily damaged. Southern Monterey County vineyards were also affected quite severely. Other parts of California generally did not suffer as extensive frost damage at the same time, suggesting a more regional focus to this weather event.

This was primarily a radiation frost event during the night, but some areas such as the Sta. Rita Hills had aspects of advection frosts, with damage observed only at high elevations. Radiation frosts are the most common frost events in the springtime in California; they are characterized by clear skies at night, with little to no wind. Under such conditions, temperature inversions are generally formed, in which the coldest air occurs near the ground surface, with air temperature increasing with altitude up to the inversion ceiling at some height; above this ceiling the air temperatures then become cooler again. Under these conditions, the most severe frost damage generally occurs in the lowest elevations within an area. In contrast, advection frosts, which are much less common in California during the spring, are characterized by the movement of a cold air mass into the affected region; such frosts often causes the most severe damage at higher elevations within an area.

This frost event was much more severe than most regional weather forecasts had predicted; this unexpected increase in severity can be attributed in some part to the local weather patterns in the days immediately preceding the frost. These days were characterized by cool, overcast and stormy weather during the daytime, followed by very clear skies at night. This combination reduced the incoming solar radiation during the day, leading to less warming

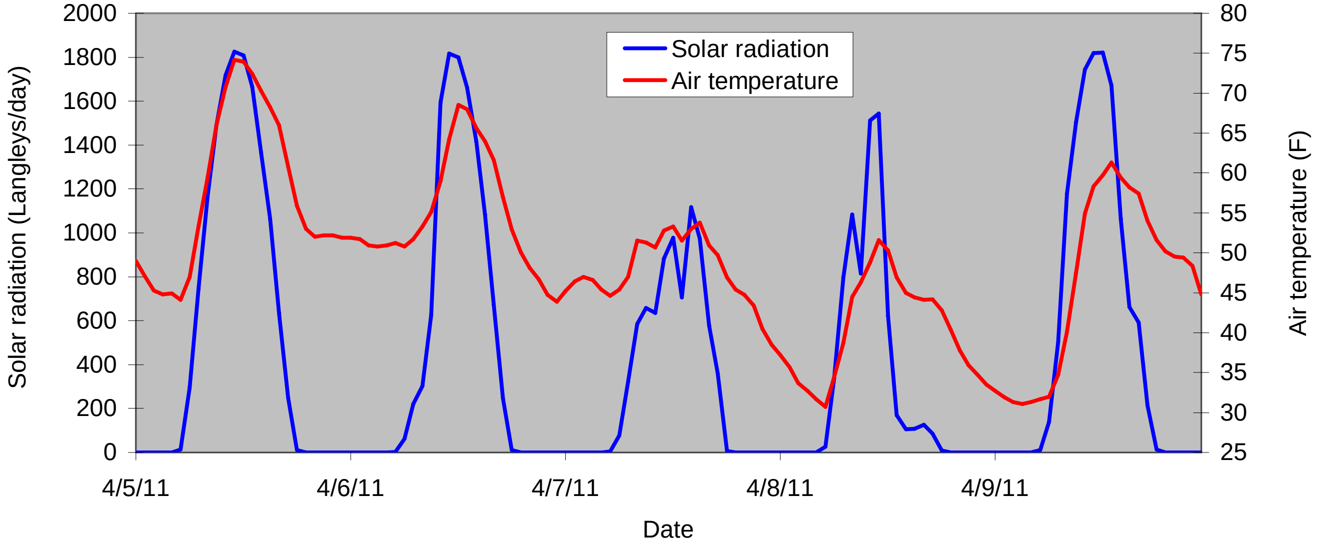

Figure 1. Solar radiation and air temperature measured at the Santa Ynez CIMIS station, April 5-9, 2011. The cloudy daytime conditions on April 7 and 8 are indicated by the low solar radiation values and much cooler temperatures. With less solar radiation, less heat is stored in the soil which can warm the air during the following nights. The air temperature at this station, close to the Santa Ynez River, did not drop as low as other nearby areas at higher elevations.

of the ground surface, while the clear skies at night allowed for large losses of stored heat through surface radiation. This pattern was particularly strong on April 7 and 8, when incoming solar radiation was reduced to only about 50-60% of full potential radiation in many areas and daytime air temperatures dropped accordingly (see Figure 1). By the later evening on April 7 the skies had become very clear, allowing for rapid loss of the stored heat from the surface. The very clear nighttime skies continued for the following two days, contributing to the extended period of cold nighttime temperatures.

Vineyards with properly working sprinkler frost protection generally suffered little damage, whereas wind machines were not effective in areas where temperatures dropped very low. This reduced effectiveness of wind machines for this particular frost event indicates the intrinsic limitation of wind machines in general, in that they can only warm the target vineyard if air of adequate warmth exists higher up in the inversion layer.

Wind machines take advantage of the warmer temperatures of the inversion layer by mixing this warmer air with the colder air that has formed near ground level. In general, conventional wind machines can be expected to raise the temperature of the air at vine level by about 1/3 the difference between the temperature at the vine level and the temperature at the height being blown by the machine. For example, if the temperature at 5 feet elevation is 28 °F and the temperature at 40 feet elevation is 34 °F, then the operation of the wind machine can be expected to raise the temperature at 5 feet elevation by about 2 degrees. The smaller the difference in air temperature between the vine level and the height being blown by the wind machine, the smaller the gain will be achieved in warming the crop.

The author happened to be in a vineyard east of Templeton in the early morning hours of April 8, 9, and 10, launching weather balloons to measure the temperature inversion characteristics at this site. These measurements indicate that while temperature inversions did exist on all nights (Figure 2), the temperature of the air at heights which could be reached by conventional wind machines was still colder than the threshold damage temperature of the vines on the mornings of both April 8 and 9. Thus the operation of wind machines would not have been expected to prevent crop damage under these conditions at this site, or for other sites which had similar temperature patterns. The temperature inversion conditions throughout the local region may have followed similar general patterns, but these conditions can vary widely based on local topography; therefore an on-site measurement is the only accurate way to determine local inversion behavior. The very different pattern of frost damage observed in the Sta. Rita Hills and potentially other parts of Santa Barbara County suggests that different temperature profiles existed there.

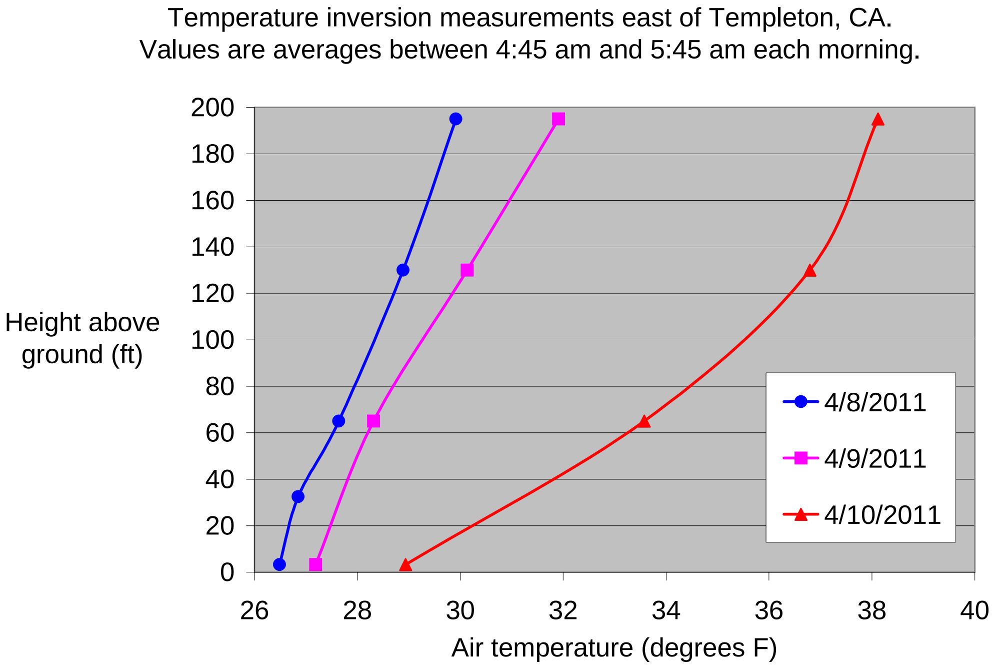

Figure 2. Temperature inversion conditions measured east of Templeton on the mornings of April 8, 9, and 10, 2011. Measurements were made at a low-lying area, and likely indicate relatively colder temperatures than experienced at nearby higher elevations. The measurements were made by sending a large helium balloon aloft carrying precision temperature dataloggers at multiple heights during the early morning hours. The points on the lines indicate the heights where measurements were made.

The characteristics of the temperature inversion will play a very big role regarding the effectiveness of a wind machine for any given frost event. Temperature inversions can be "strong" in which there is a marked increase in temperature with height above the ground, or "weak" in which there is less increase in temperature with height. Wind machines will be more effective with strong inversions, and less effective with weak inversions. Again looking at Figure 2, the early mornings of April 8 and 9 had relatively weak inversions, while April 10 had a much stronger inversion. This combination of weak inversions and very cold temperatures can explain why wind machines were not effective at some locations for the mornings of April 8 and 9, even where they had worked very well for past events. If the inversion conditions had been stronger like April 10, then wind machines would likely have been more effective. The existence of damaging temperatures at relatively high altitudes on April 8 and 9 also helps explain why growers observed frost damage at surprisingly higher terrain elevations than had been observed in past frost events, where damage usually tended to be confined primarily to the very lowest areas in the local landscape.

Sprinkler frost protection generally performed well during this event, as the minimum air temperatures were within the limitations of this method and the lack of significant wind reduced the risk of inadvertent damage. With sprinkler frost protection, the heat which maintains the vine tissues above freezing comes from the continual process of active freezing of water which coats the vine (Figure 3). Anything which interrupts this process, such as the loss of water supply or an inadequate application rate, will result in even more damage than for an unprotected vineyard. Luckily, such problems were not widespread, but did occur in some areas. Sprinkler frost protection requires lots of water, often 1 inch or more per night when running conventional impact sprinklers. Many vineyards simply do not have access to this amount of water, making sprinkler frost protection an unavailable option in some areas. The trend throughout the state is that water supplies available for sprinkler frost protection are tending to diminish over time; hence more efficient use of the water or alternative frost protection measures will need to be found.

Steps to reduce radiation frost damage

Reducing the potential for springtime radiation frost damage in those vineyards without sprinkler frost protection should focus initially on passive frost protection measures. These are practices which are carried out well before the danger of frost, which are intended to accomplish two things:

1) To store as much of the heat energy of solar radiation in the soil, which will then contribute to higher air temperatures on subsequent cold nights
2) To ensure that any accumulated cold air can readily drain away from the vineyard

The optimal soil condition for storing the heat from solar energy is a bare, firm, moist soil. This allows the sunshine to strike the soil, and for the heat to be conducted and stored deeper in the soil. This process is not as efficient for soils which are dry, or which have many insulating air pockets due to recent tillage.

Actively growing cover crops, while providing many benefits, are detrimental from this aspect because their presence leads to cooler soil temperatures and subsequently lower nighttime air temperatures as compared to a bare soil. Closely mowing the cover crop well prior to the frost period will improve airflow, but the residues on the surface still function as insulating mulch which lowers overall temperatures. Growers in frost-prone locations who are relying on passive frost protection measures need to find an appropriate balance between the benefits of keeping the cover crops actively growing in the spring and managing the vineyard floor in a way that reduces the risk of frost. In general, hillside vineyards have relatively less risk of frost and need the soil protection of cover crops, so these sites will benefit more from allowing the cover crops to continue growing in the spring. In contrast, flat low-lying vineyards have less need for erosion protection and are more prone to frost damage, and hence it may be more beneficial to manage the vineyard floor with the goal of reducing frost damage at these locations.

Ensuring that cold air can drain from a vineyard is most efficiently achieved at planting time through proper

Figure 3. A spur with newly emerging shoots encased in an ice/water mixture from sprinkler frost protection. Heat is created from the continual freezing of water; if the water application is insufficient or stops, then the vine tissues will quickly freeze.

site selection by intentionally avoiding frost pockets and other low-lying areas where cold air will accumulate. The cold air which forms near the ground surface on a radiation frost night is slightly denser than the surrounding air, and will tend to slowly flow downhill, accumulating wherever natural or man-made barriers prevent its further movement. Cold air drainage out of a vineyard can be encouraged by orienting the rows with the slope, by keeping ground covers well mown, and by removing any physical barriers to air movement at the lower edges of the vineyard such as hedgerows or fences. Depending on the location, it may be beneficial to use barriers to reduce the inflow of cold air drainage from parcels uphill from the vineyard. By driving around and looking at the patterns of frost damage that are visible in vineyards right now, one can visualize how the cold air moved throughout the different areas; often very slight differences in elevation and the presence of airflow barriers can lead to very different outcomes with regards to frost damage.

What to do with a frosted vineyard?

The majority of recently frosted vineyards were just beginning to show new shoot growth when they were damaged, and these shoots were generally completely killed back by the frost. Where the emerged primary shoots were frosted, the vine will respond with the growth of the secondary buds from within the same compound bud from which the primary shoot had recently emerged (Figure 4), and from basal buds. However, these replacement shoots are often significantly less fruitful compared to the primary shoots, and thus crop production this season will usually be reduced considerably for frost-affected vineyards, often by half or more.

The biology of the grapevine is to begin forming the current season's flower clusters during the spring of the preceding season, hence extra fertilizer or irrigation this spring will not create more flower clusters for this year. However, it is important to continue taking proper care of the vineyard, including disease control and adequate nutrition, as this will help ensure that one can maximize the full potential crop this year and will help ensure that next year's crop will not suffer inadvertently. One positive consequence of the reduced crop load this season is that the same vines will generally compensate by producing a larger-than-average crop next season, all else being equal, provided that they are not unduly stressed or neglected this year.

Figure 4. The April 2008 frost damaged the primary shoot that had emerged from this bud; the dead shoot with its flower clusters has remained in place. The vine responded by growing two additional shoots from the same compound bud. These secondary and tertiary shoots are less fruitful than the primary shoot, hence crop yields will be lower than if the primary shoot had not been frosted.

As the danger of frost continues into late May for most of this area, it is very important maintain frost protection efforts because if the newly emerged secondary and basal shoots themselves become damaged from another frost event, then the next batch of replacement shoots will generally have even less potential for producing any crop.

For more background on general frost protection theory and practices, please see the two websites listed below.

Additional frost protection information:

http://cesanluisobispo.ucdavis.edu/Viticulture/Frost_Protection/

http://biomet.ucdavis.edu/frost-protection.html

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A group of UC faculty and staff are spearheading a project to scan and digitize the entire *Hilgardia* series (more than 31,000 pages), bringing these scarce classic publications to light. About one-half of published *Hilgardias*, including the first 24 volumes and 58 other editions, are now out of print. When complete, the digital series will be added to the searchable online archives of *California Agriculture*.

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