Helicopters and Frost Prevention: A Preliminary Evaluation

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Introduction

The importance of minimizing frost damage in the deciduous orchards of southeast Arizona needs little elaboration following the devastating killing frost of 1987. While site selection and cultural practices can go a long way toward minimizing problems with frost, there are times when the use of some form of active frost protection is warranted. One method of active protection that has potential and is presently used in several areas of the state involves the use of helicopters to mix warmer, above-ground air down into the orchard on cold nights. Reports on the use of helicopters in the fight against frost go back as far as the 1940s; however, the available literature on the subject presents little hard information on the value of the technique. Much of the past research was unable to accurately document the benefits resulting from the use of helicopters -- in particular, improvements in orchard temperature. In the spring of 1988 a small study was initiated in the Bonita area to obtain some preliminary information on the value of using helicopters as an active means of mitigating frost damage. The following report summarizes the findings of this study.

Methods

This study was conducted in an apple orchard managed by Bonita Valley Apple Co. during the evening and early morning hours of 1 and 2 April 1988 respectively. Temperature sensors consisting of fast-response, fine-wire thermocouples were attached to apple trees (cv. Red Delicious) at varying heights (3 to 12' above ground) in two distinct regions of the orchard. Tree height ranged from 9 to 12' in the study area. The output of all sensors was monitored at 20-second intervals throughout the course of the study using an automatic datalogging device which stored the incoming data on magnetic tape.
Helicopter overflights were initiated at ~ 3:30 a.m. on 2 April when orchard temperatures approached the freezing level. Bell Jet Ranger helicopters (model 206B2 or 206B3) weighing approximately 2900 lbs (including passengers and fuel) were flown over the study area at an altitude of 20-35' above tree level. Helicopter ground speed was maintained between 15 and 20 mph. Ground personnel monitored the overflight process, documenting the timing and location (relative to the temperature sensors) of each overflight.

At the conclusion of the study, the data tapes were transported to Tucson where the temperature data were transferred to computer, checked for possible errors and entered into a commercial database management system. Selected portions of the data were then subjected to further analysis to determine the magnitude and longevity of the temperature increases produced by helicopter overflights.

Results and Discussion

An inversion must be present for helicopters to provide any benefit as a frost prevention device; that is, temperatures aloft where the helicopter is flying must be warmer than temperatures within the orchard. While a true inversion tower (30-50' tower with temperature sensors located at 2 or more heights above the ground) was not installed on the night of this study, the measurement of temperatures at several levels within the orchard clearly showed the presence of an inversion (Figure 1). Temperatures at 9' above the surface were typically 1.5° to 3.5° F warmer than temperatures at 3' above the surface (Figure 1).

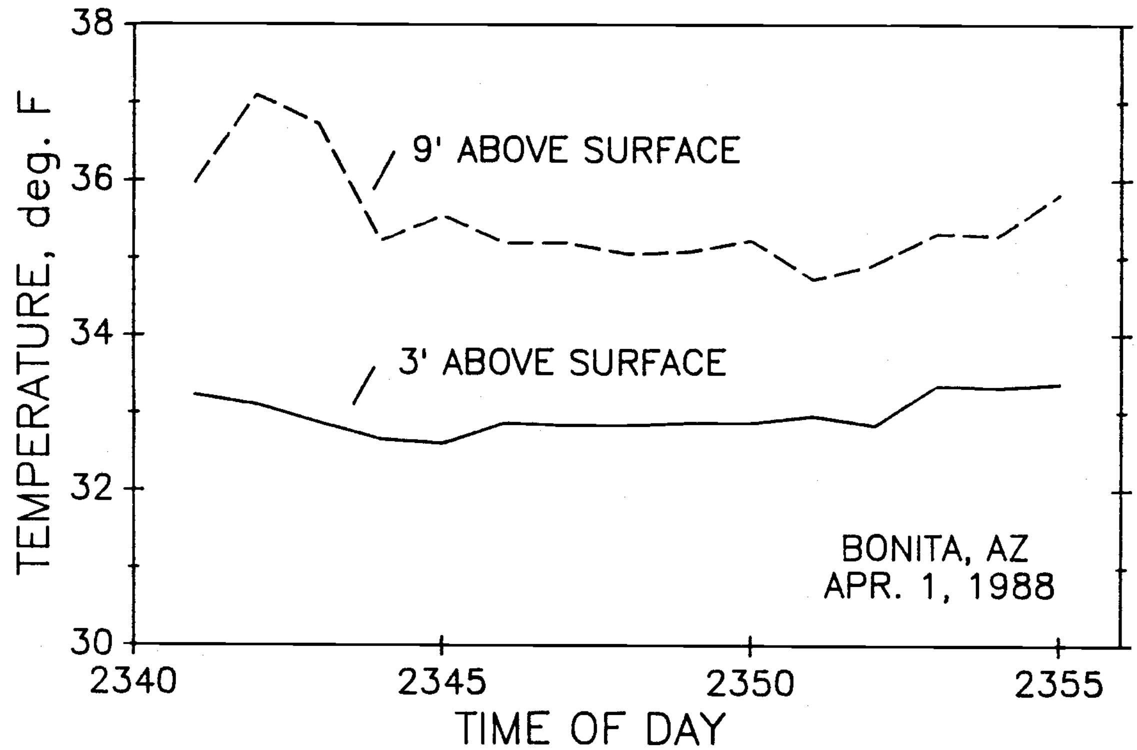

Figure 1. Air temperatures recorded at 3' and 9' above the orchard floor clearly show the presence of a temperature inversion.

The effect of a single helicopter pass on orchard temperature at 3' is shown in Figure 2. Measurements made at other heights within the orchard showed a similar response and are not presented to minimize confusion in Figure 2. Temperature increases in the orchard were rapid and large as a result of the passage of the helicopter. The temperature rise of nearly 6° F shown in Figure 2 was typical during this particular night. While the magnitude and suddenness of the temperature rise are impressive, it is of equal importance to notice how quickly temperatures fall following the passage. Temperatures declined to levels observed prior to the presence of helicopter within 5 minutes. This rapid fall in temperatures is likely caused by a combination of factors including 1) the replacement of the warm air by cold air drainage winds, 2) radiational cooling and 3) horizontal displacement of cold air by the helicopter itself. Each of these factors is briefly discussed below.

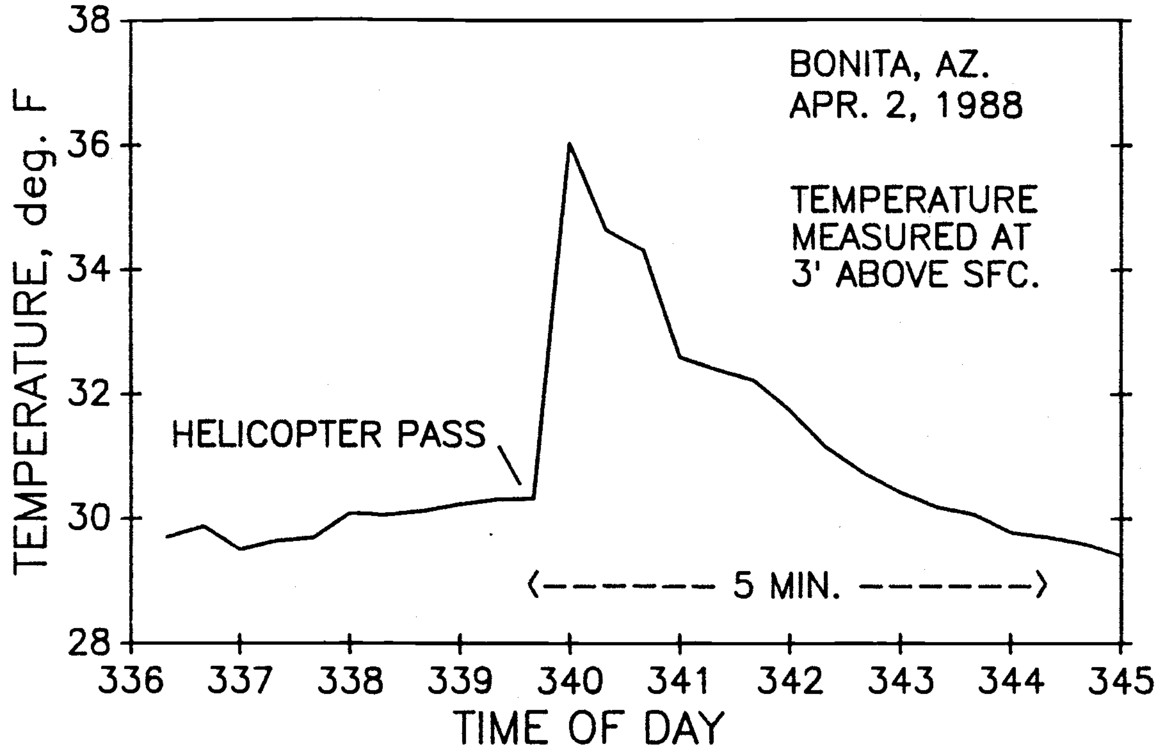

Figure 2. Air temperature at 3' above the orchard floor prior to, during and following a single pass of a helicopter.

Cold air driven by the ever-present drainage wind is likely a major factor contributing to the rapid fall in temperature following the passage of the helicopter. A helicopter typically affects air temperatures on either side of the flight path for a distance of 100-150'. During the period depicted in Figure 2, winds were from the northwest at 2.1 mph(according to the nearby AZMET station). Such a wind, if perpendicular to the flight path, could displace the strip of air modified by the helicopter (200-300') in 60-90 seconds if vegetation in the orchard offers minimal wind resistance. Little foliage was present on the trees utilized in this study so it is likely that drainage winds flowed through the orchard with relative ease on this particular night.

Radiational cooling of various surfaces in the orchard also contributed some to the rapid fall in temperatures after passage of the helicopter. Skies were clear and the air was dry (dewpoint temperature was 14° F) on the night of this study--a situation conducive to high radiative cooling.

Finally, the helicopter itself may be partially responsible for the rapid post-passage drop in temperature. The helicopter warms the air near the surface by mixing warm air aloft with colder air near the surface. However, in the process of this mixing, some of the cold surface air is displaced horizontally--a fraction of which moves back over the area just covered by the helicopter. The importance of this horizontal displacement of cold air on the rapid post-passage fall in temperatures is not clear from this study or the scientific literature, but several past research studies have suggested that multiple helicopter passages in rapid succession are necessary to obtain maximum benefit (warming) from the helicopter. While these studies do not clearly state why successive passages are necessary, it is possible that successive passes gradually warm up these pockets of cold surface air that are continually being displaced around the orchard by the helicopter.

The temperature record presented in Figure 3 adds support to the idea that multiple helicopter passes within a brief time span may improve the effectiveness of the technique. During the initial 15 minutes of the 30-minute time sequence presented in Figure 3, one can observe at least 3 passes of the helicopter (designated by an H in Figure 3). While temperatures fall fairly quickly following each helicopter pass, note that following the last pass, the temperatures hold above levels observed prior to the first passage for an additional 15 minutes. The protection obtained by using the three helicopter passes in this manner lasted about 30 minutes or 10 minutes per pass. This should be compared with Figure 2 where a single pass provided only 5 minutes of protection.

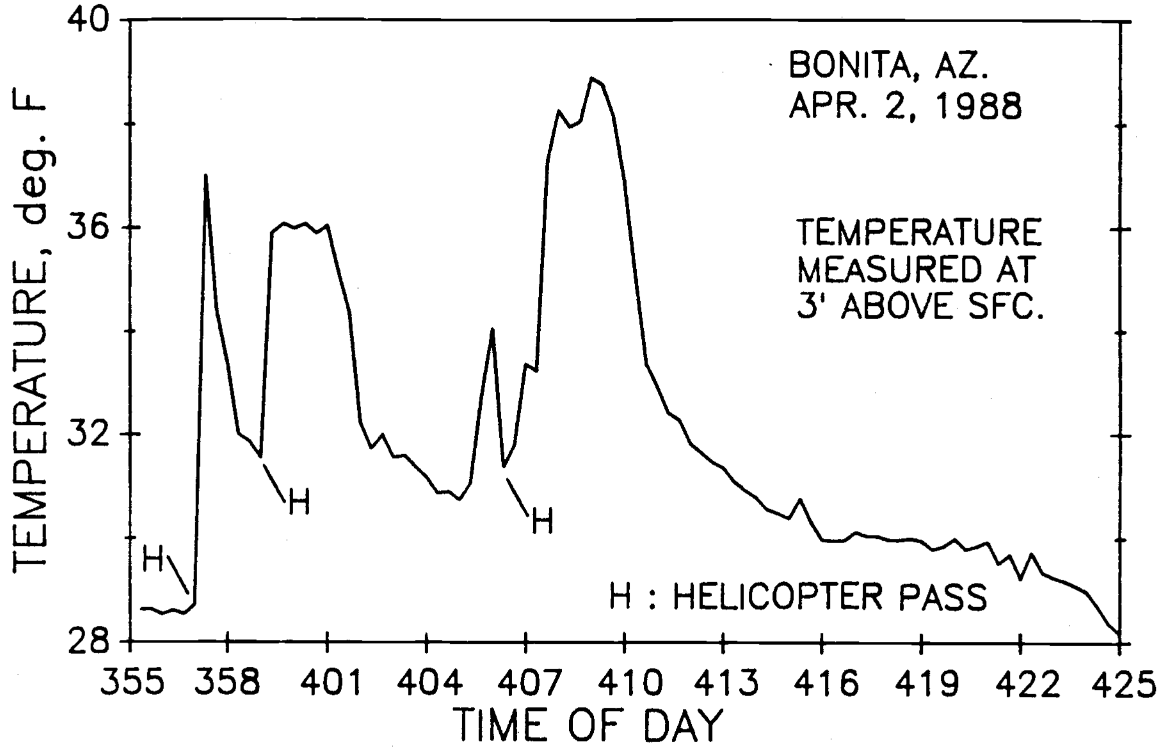

Figure 3. Response of orchard temperature to multiple passes of a helicopter. Air temperature was recorded at 3' above the orchard floor.

Conclusions

Based on this preliminary study, it appears helicopters can be an effective tool in the fight against spring frosts. However, the results presented here do suggest that protection afforded by a single helicopter pass is short-lived, and that multiple passes performed in rapid succession may be a more effective method of increasing orchard temperatures.

It also must be emphasized that the results presented here are from a small, preliminary study. A larger and more sophisticated study is necessary to better refine the technique for use in southeast Arizona. Among the factors needing further research and study are 1) the effect of helicopter size, speed and flying altitude on orchard temperature and 2) the effect of inversion strength and wind speed on the effectiveness of helicopters. Improved knowledge in either of these two research areas would allow for more effective and efficient use of the helicopter as a frost protection device.

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