Real-time Weather Monitoring for Frost Protection Sprinkler Operations in Almond Orchards

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Objectives:

1. Develop an automated computer-based model to monitor real-time weather conditions in orchards as a basis for managing sprinkler operations for frost protection.
2. Develop guidelines for using the model to manage sprinkler operations on radiation frost nights.

Background:

A perennial question that besets almond growers seasonally is whether to use sprinklers to protect against frost, and when to turn them on and when to turn them off. Starting sprinklers too late and stopping too early can result in frost damage. To avoid damage, sprinklers should be started and stopped when the upwind wet-bulb temperature is above the critical damage temperature. Our goal is to combine continuously recorded temperature and humidity data with a wet-bulb forecast model to update and improve predictions of the wet-bulb temperature. This will provide the information needed to time the timing of sprinkler operation for frost protection.

Making poor decisions about sprinkler usage can lead to significant crop losses. Insufficient usage has obvious consequences. Under severe conditions, it is better not to use sprinklers.

Excessive usage can lead to excessive energy consumption and possibly waterlogged soils and eventually to shortages of irrigation water.

This project is designed to assist growers in making prudent decisions about sprinkler usage. It calls for developing a customized computer model for tracking and estimating wet-bulb temperature trends during radiation frost nights. The data will be transferred real-time and the model will adjust as updated meteorological information becomes available. The model will provide guidance on whether to use sprinklers and if used, starting and stopping them.

Data inputs for the model will be provided by a remote, sensor-equipped weather station set up near an orchard. The data will travel to the computer by wireless, radio, or short haul modem to a computer for processing..

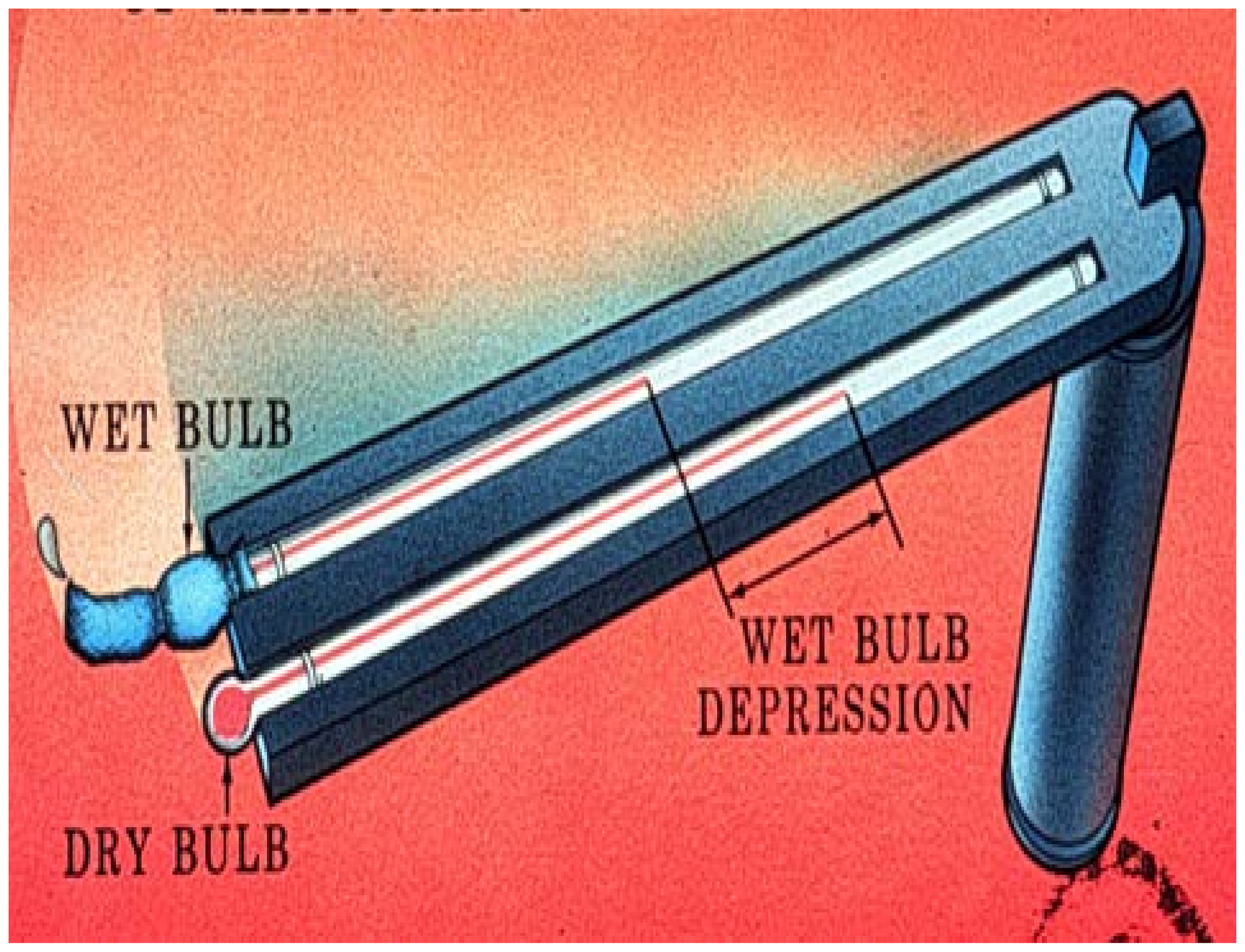

Fig. 1. Psychrometer for measuring wet-bulb and dry-bulb temperature.

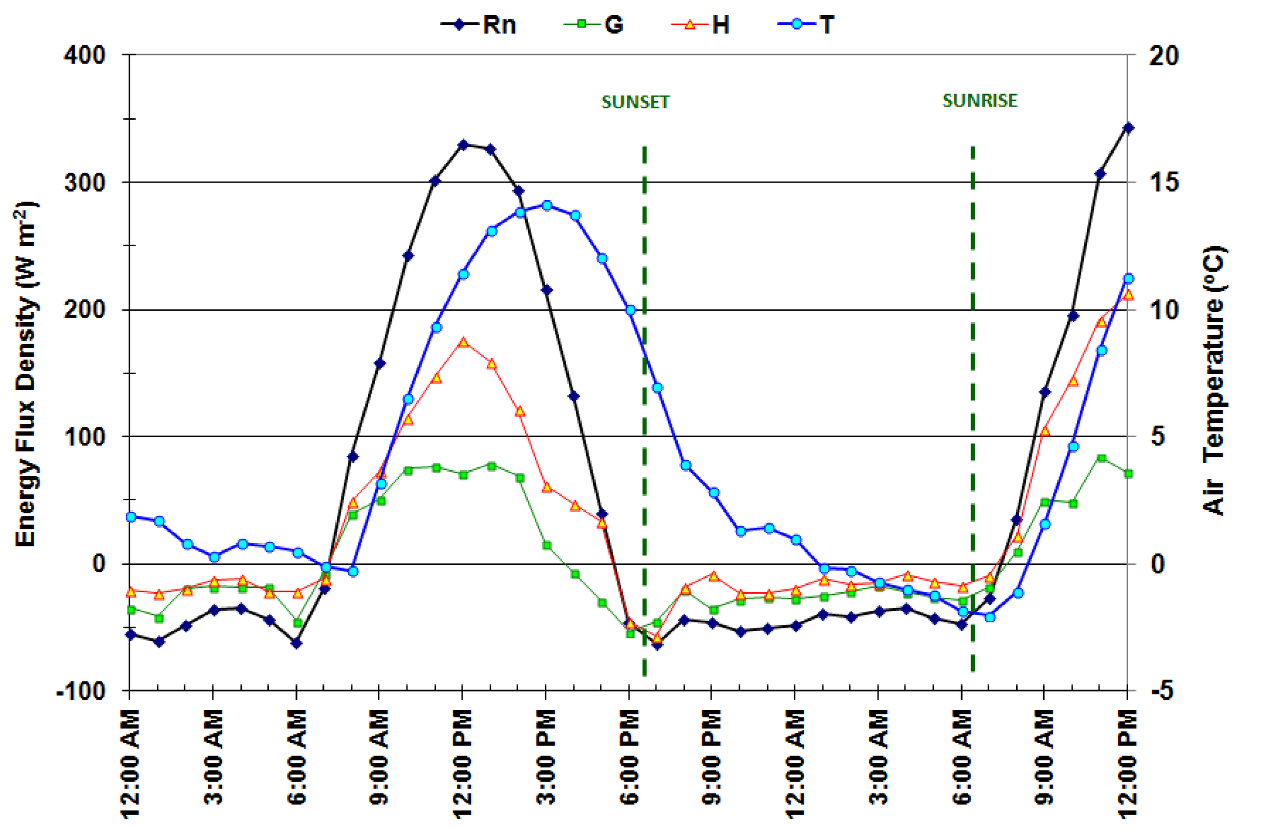

Fig. 2 This figure shows the energy balance components of a crop and the relationship with air temperature.

The net radiation (R_n), ground heat flux (G), sensible heat flux (H), and latent heat flux (LE) must balance using $R_n=G+H+LE$, where LE is the evapotranspiration. On a radiation frost night $LE\approx 0$. The air temperature (T) is related to the sensible heat flux, and the high positive H around midday indicates that heat is being transferred from the surface to the air at that time. The temperature increases as heat is added to the air and it reaches its peak slightly after the peak for H. The T drops rapidly as the R_n changes from highly positive to negative. When the R_n levels off at a negative value, the T falls at a slower rate during the night until after sunrise the next day.

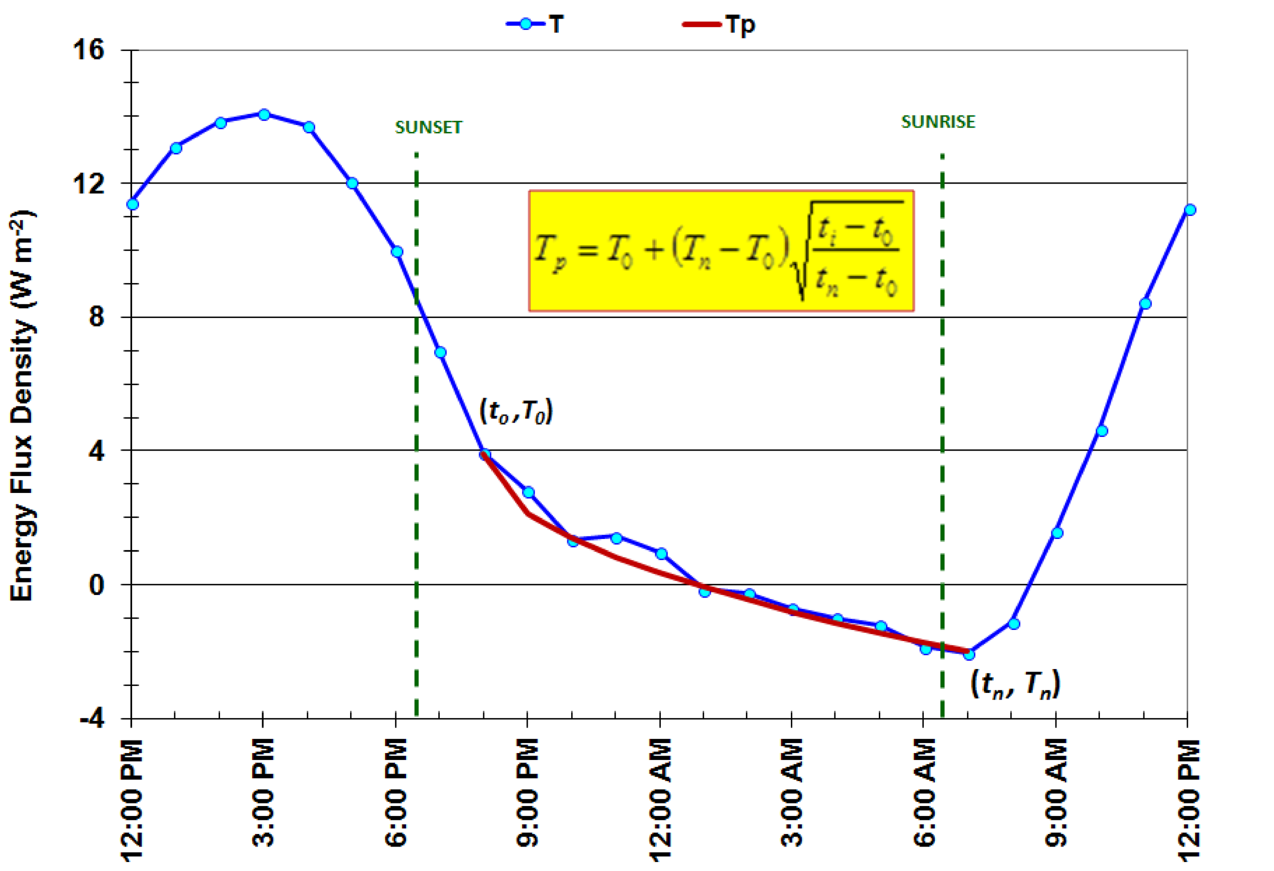

Fig. 3 This figure shows the air temperature trend model during a radiation frost night from the 2nd hour after sunset until the first hour have sunrise. During the cooling period, the air temperature trend is a function of the square root of the ratio of the time after starting to the end time. A similar model is used to predict the dew point (T_d) trend.

The wet-bulb temperature (T_w) is critical for determining when to start and stop the sprinklers, but it is not calculated by most weather stations. We developed an iterative method to calculate T_w from the elevation (E_L), T and the dew point temperature (T_d) using the psychrometric equation (below) and equations for barometric and saturation vapor pressure (not shown). We also included a program to compute the sunrise and sunset times.

$$e' = e_w - 0.00115 T_w (T - T_w) p_a$$

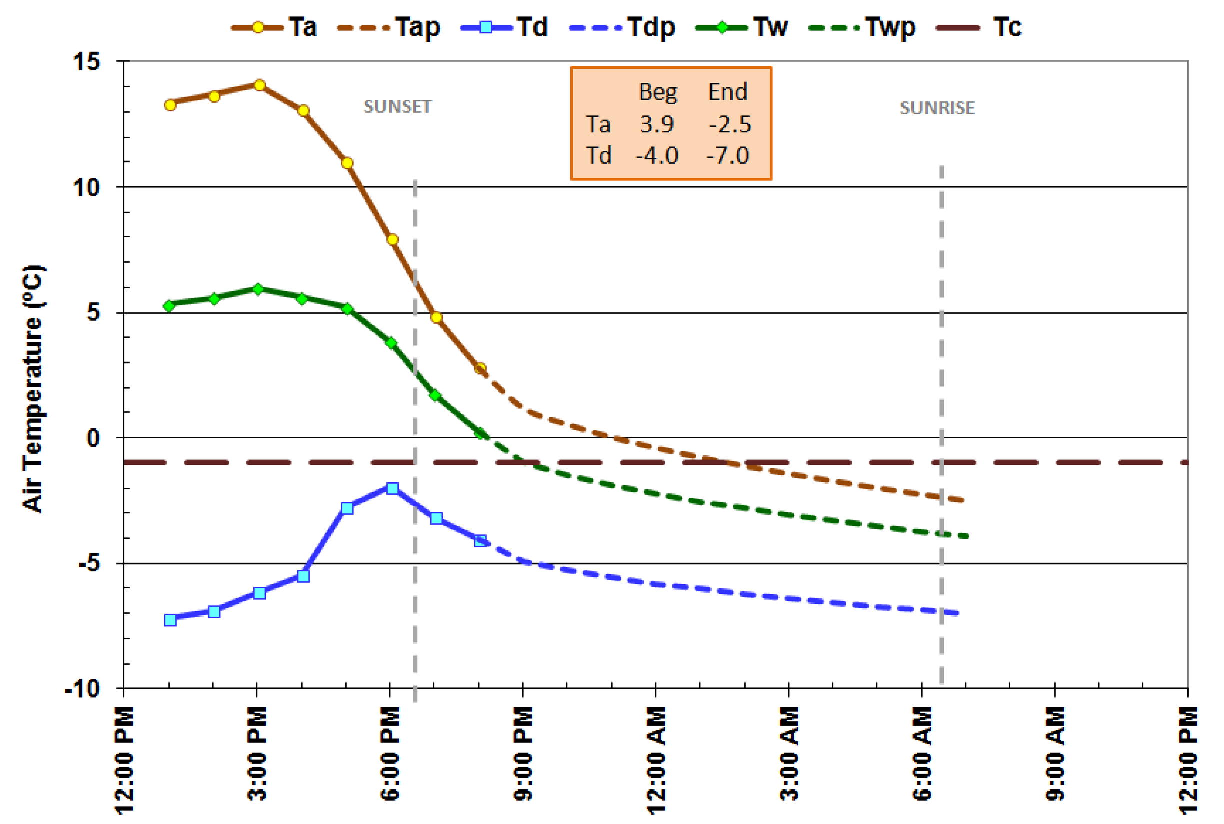

Fig. 4. This slide shows measured T and T_d and calculated T_w data until 2 hours past sunset and model predicted temperatures until 1 hour past sunrise.

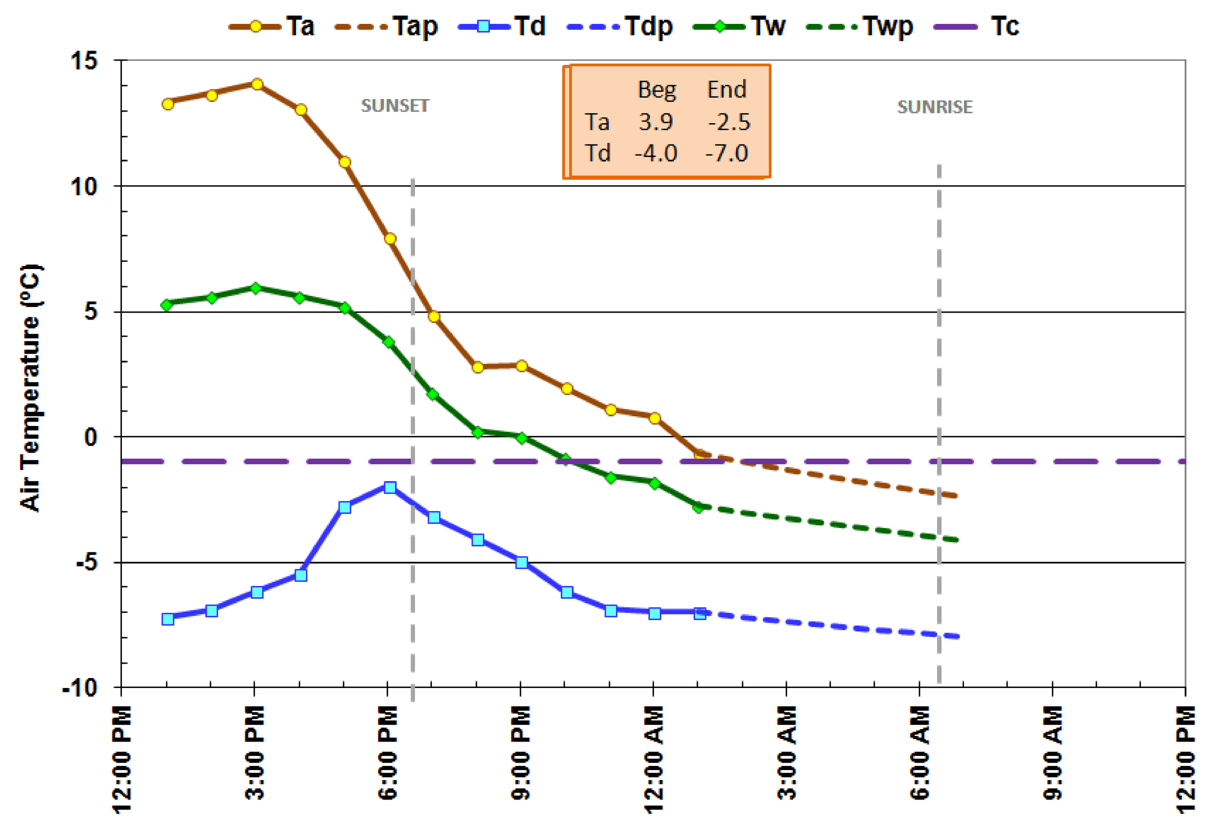

Fig. 5. This slide shows measured T and T_d and calculated T_w data until 3 hours past sunset and model predicted temperatures until 1 hour past sunrise.

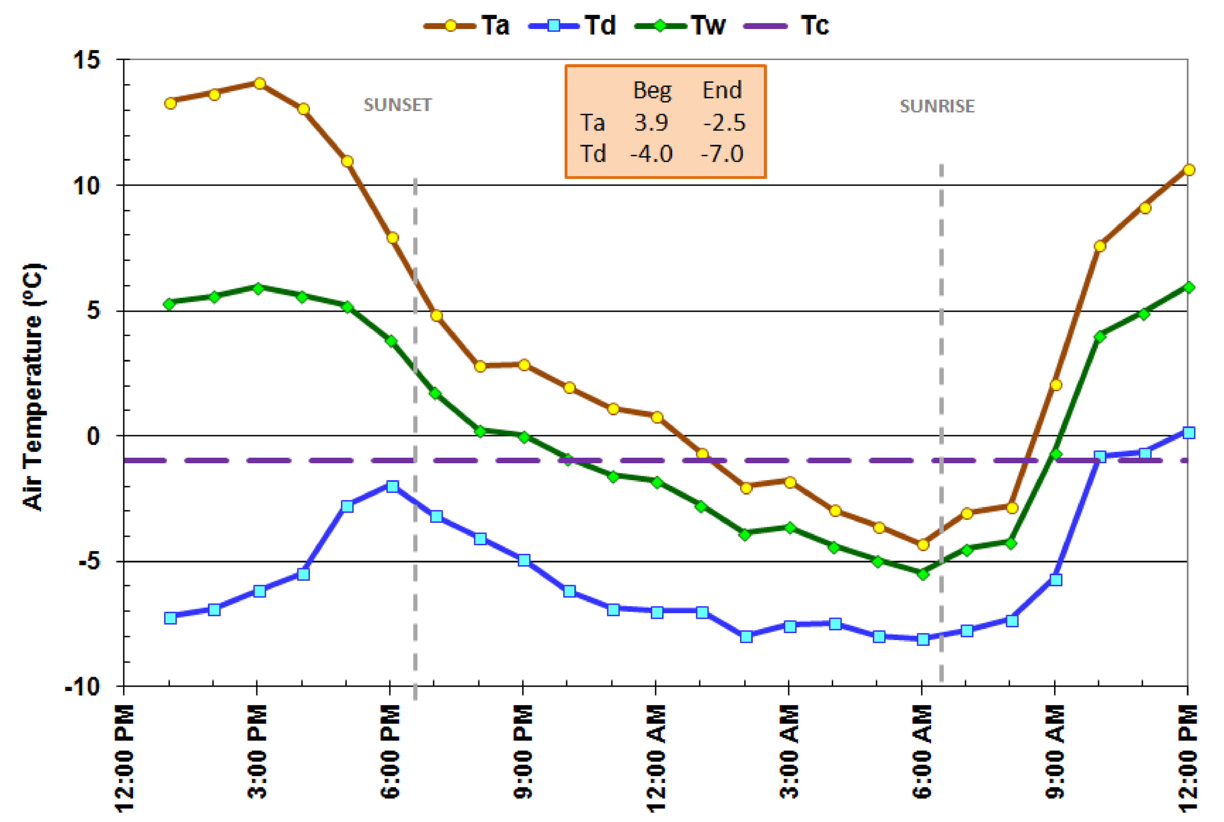

Fig. 6. This slide shows measured T and T_d and calculated T_w data during and after a frost night..

FUTURE PLANS

1. **Finish a document on how to interpret data and use the model**
2. **Provide information on critical temperatures for almond varieties**
3. **Work with weather station vendors to add the model to their station packages**

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