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Frost Protection by Water Applications

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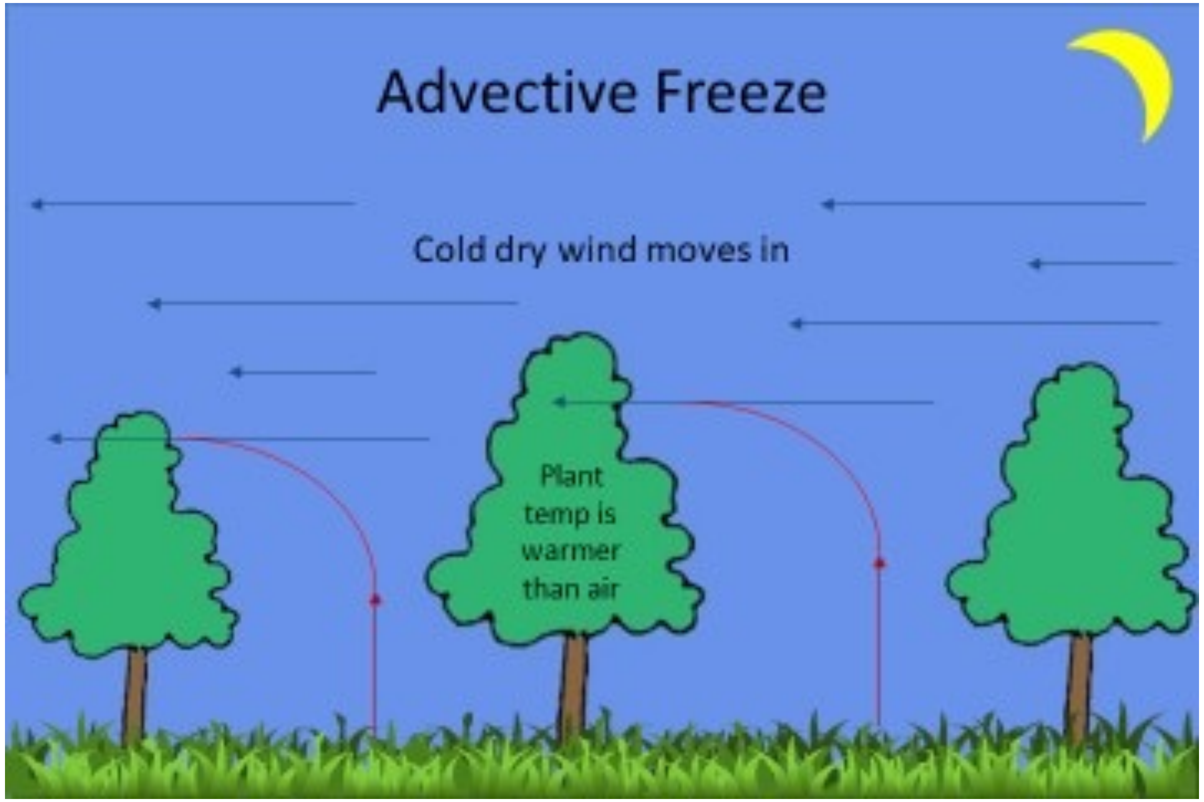
TYPES OF FROST EVENTS

Advection Frost

- Occurs when cold air blows into an area and replaces warmer air
- It is associated with moderate to strong winds and low humidity
- Often temperatures will drop below 32°F (0°C) and stay there all day.
- Advection frosts are difficult to protect against!

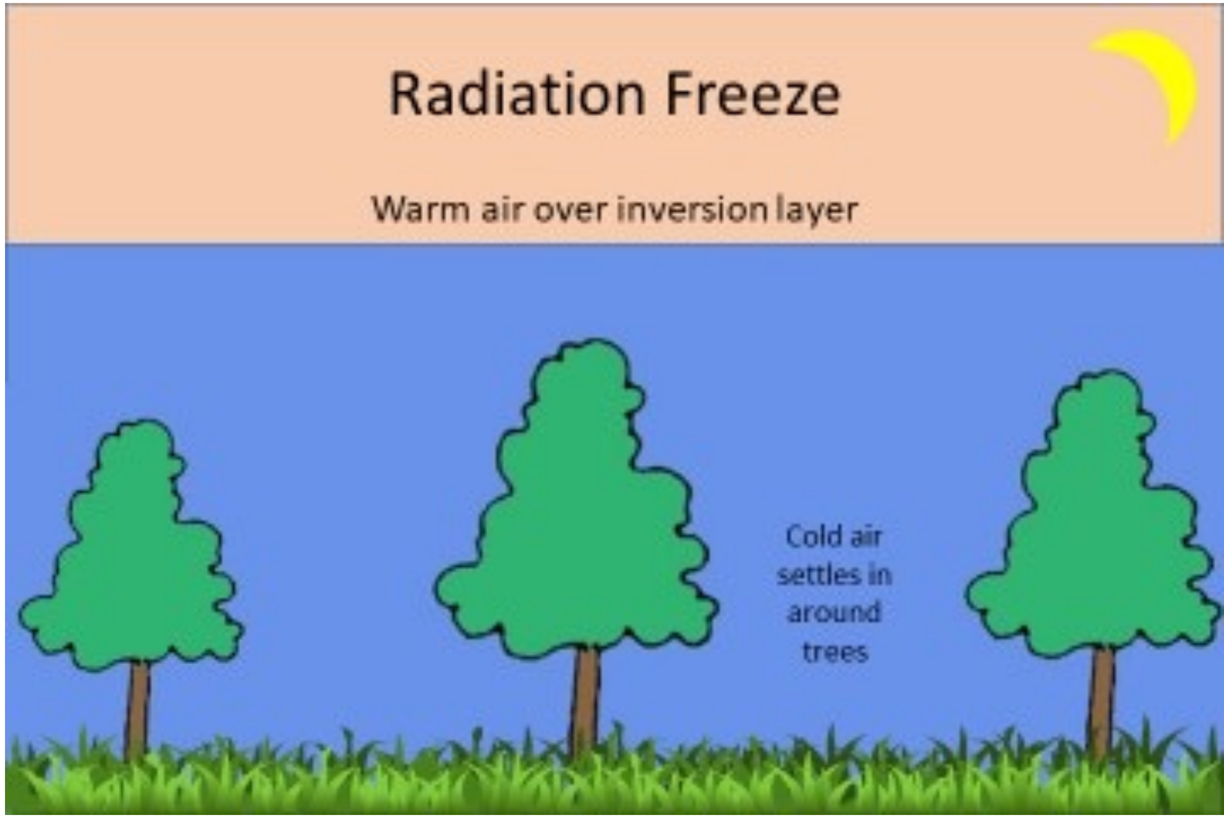


https://www.extension.iastate.edu/smallfarms/frost-protection-high-density-orchards

TYPES OF FROST EVENTS

Radiation Frost

- Are characterized by clear skies and calm winds.
- Radiation frosts occur because of heat losses from the ground to the atmosphere.
- The temperature falls faster near the radiating surface causing a temperature inversion to form (temperature increases with height above the ground).
- Hoar (white) and black types



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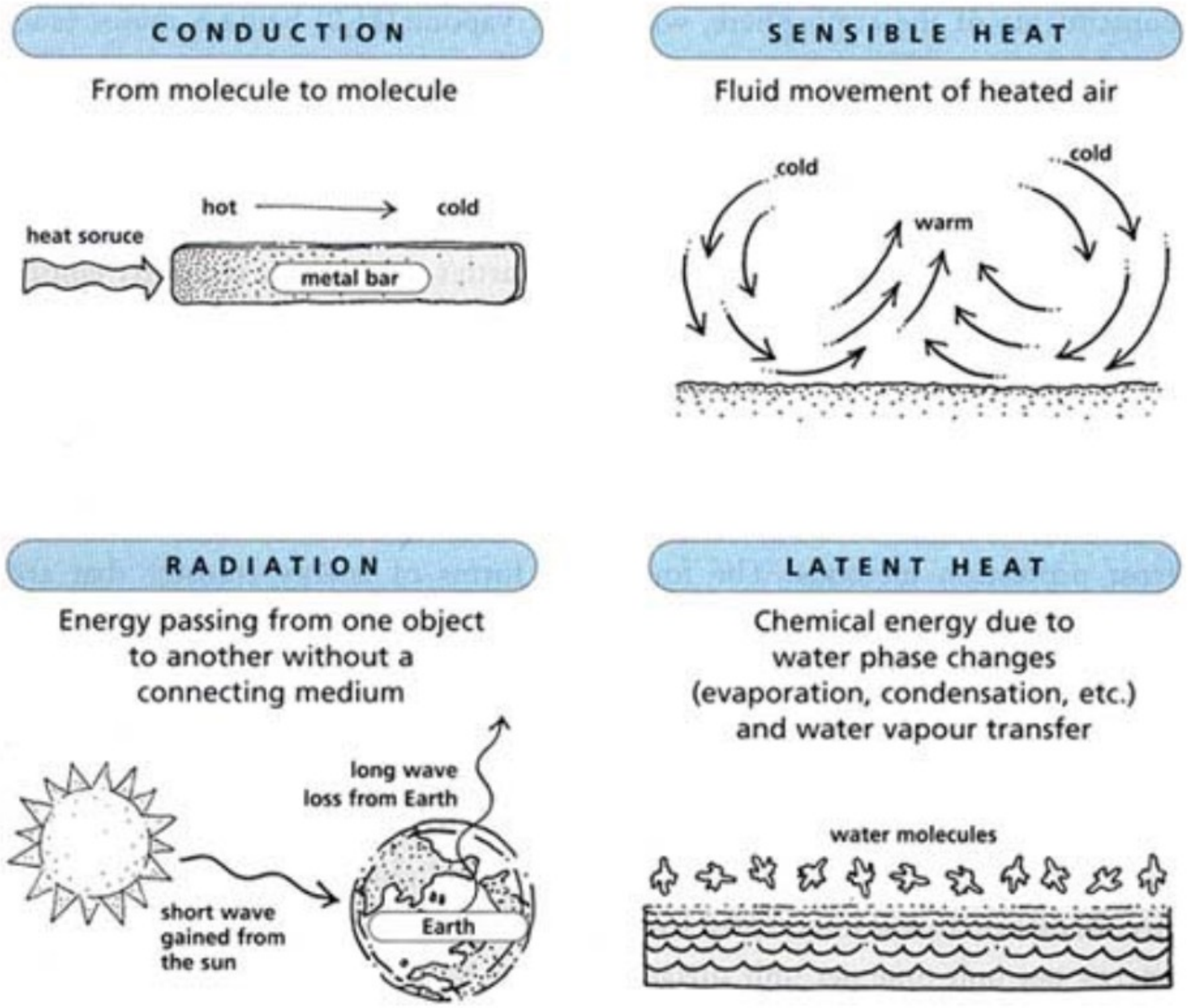
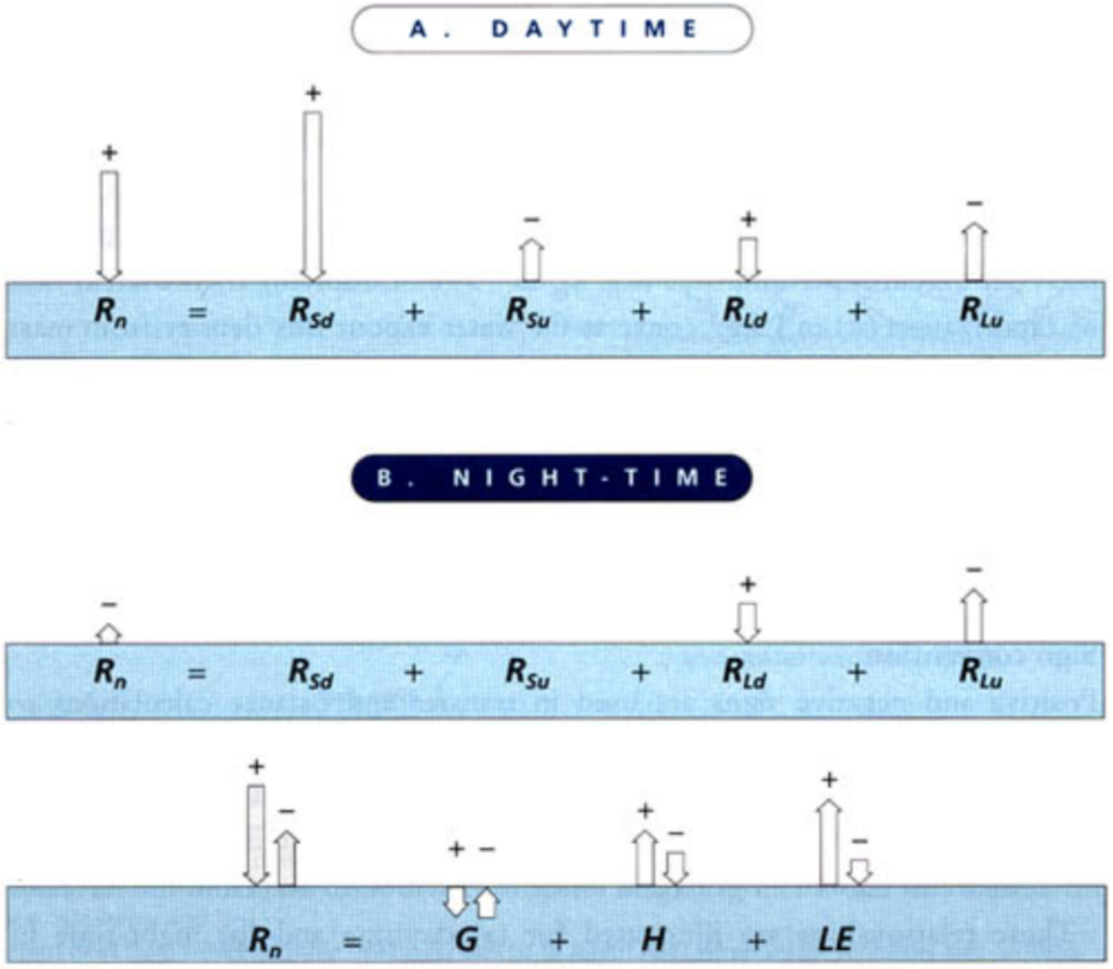
The four forms of heat transfer

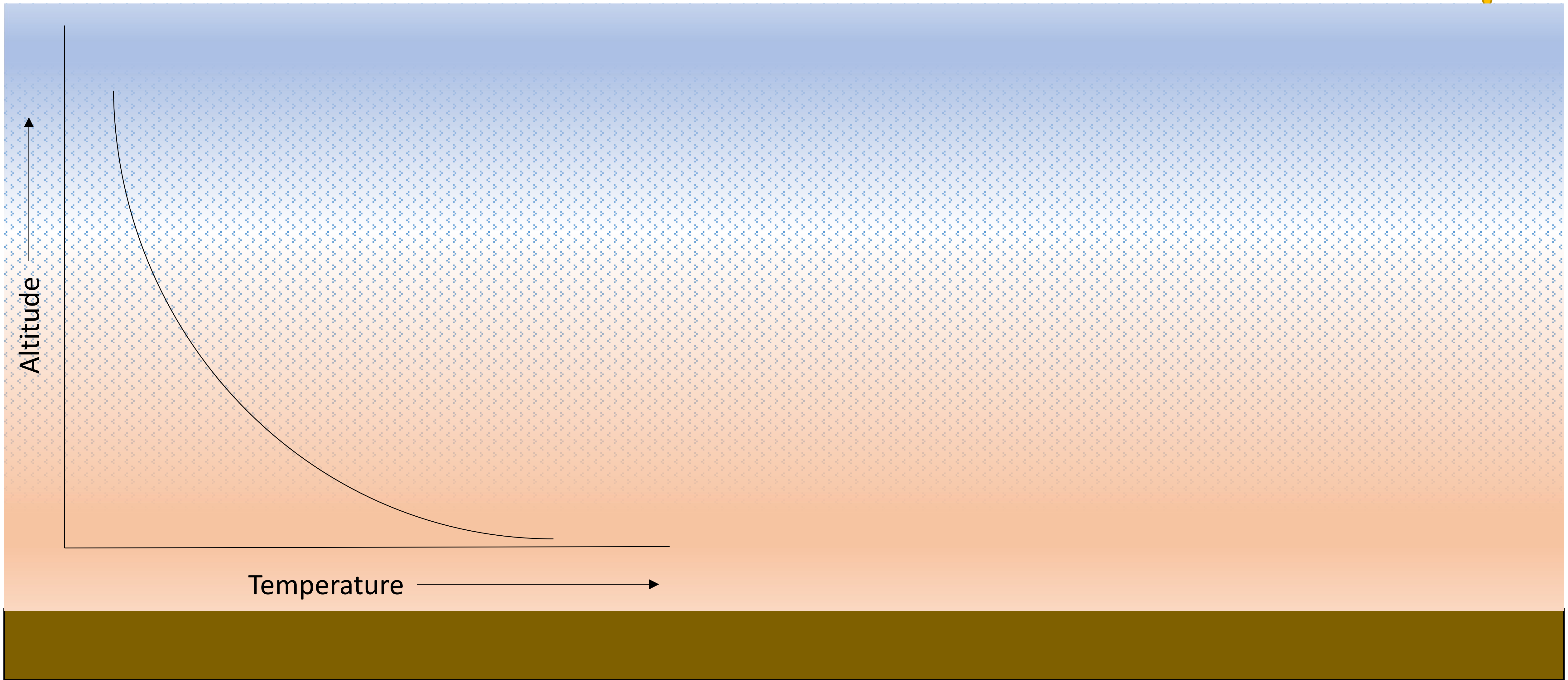


Surface energy balance

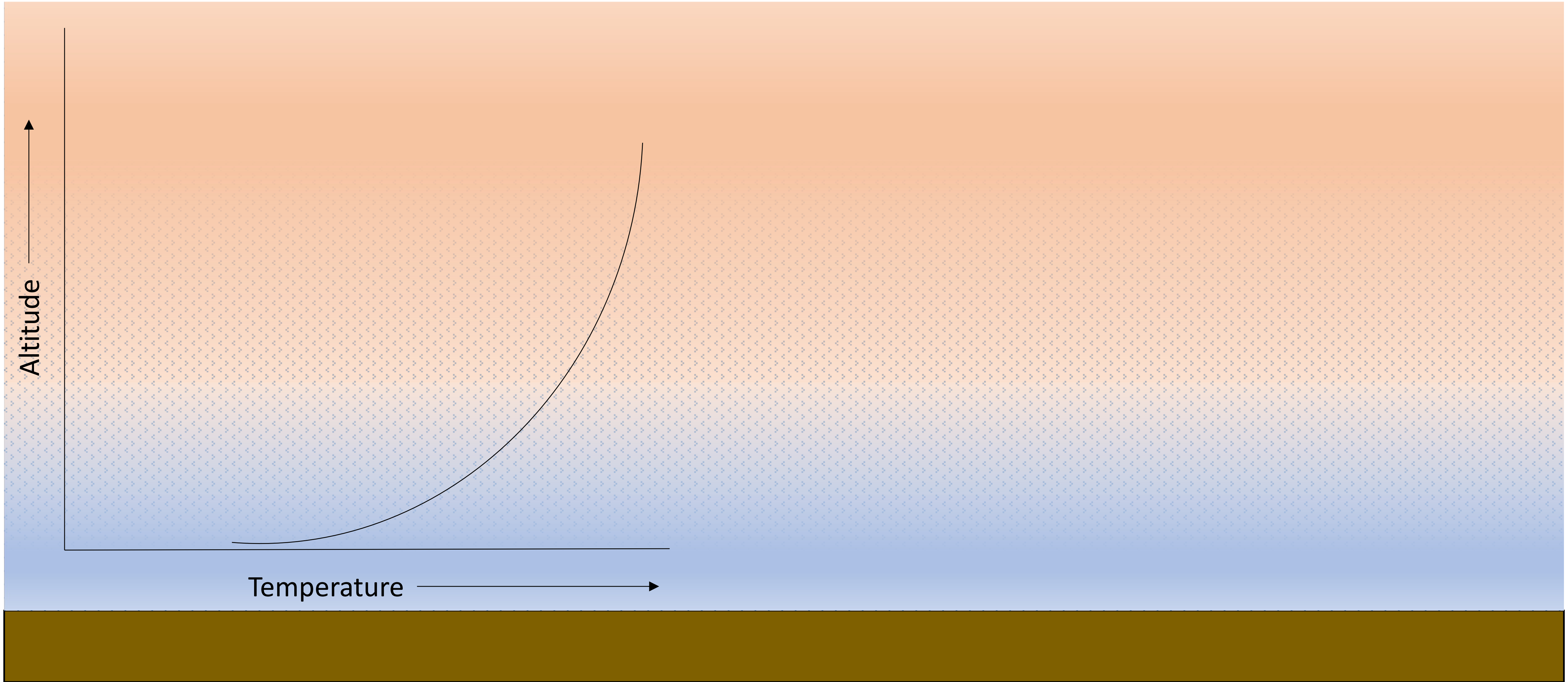


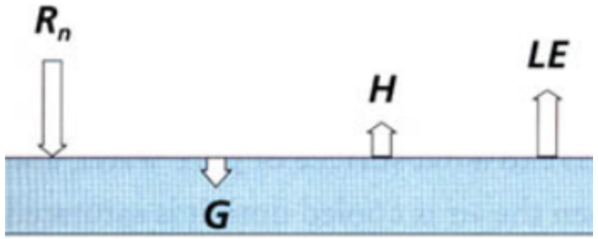
Snyder and de Melo-Abreu (2005)

Daytime Planetary Boundary (Surface) Layer

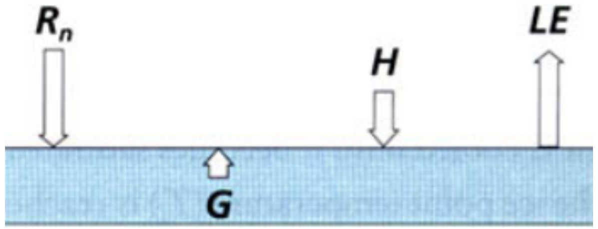


Nighttime Planetary Boundary (Surface) Layer

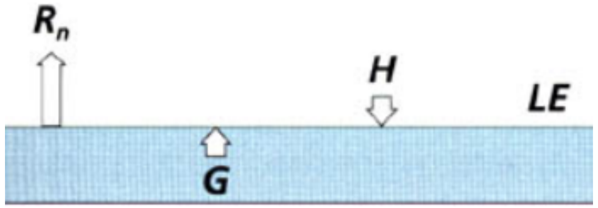




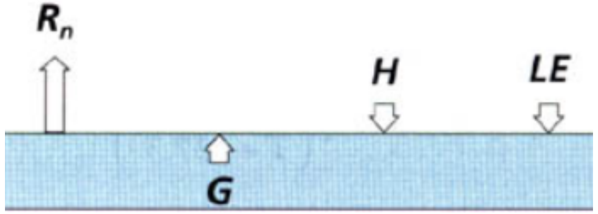
Mid-morning summer energy balance



Mid-afternoon summer energy balance



Pre-dawn *radiation frost* energy balance



Pre-dawn *radiation frost* energy balance with condensation

Snyder and de Melo-Abreu (2005)

FROST DAMAGE IN PLANTS

- Freeze injury occurs in all plants due to ice formation.
- Frost happens under conditions when the air temperature drops below critical temperatures for particular crop
- Some adaptation to cold temperatures prior to a frost night is possible and it is called "hardening“
- During warm periods, plants grow and reduce solute concentration, which makes the plants less hardy.
- Ice-nucleating bacteria increases the risk of frost damage at higher temperatures

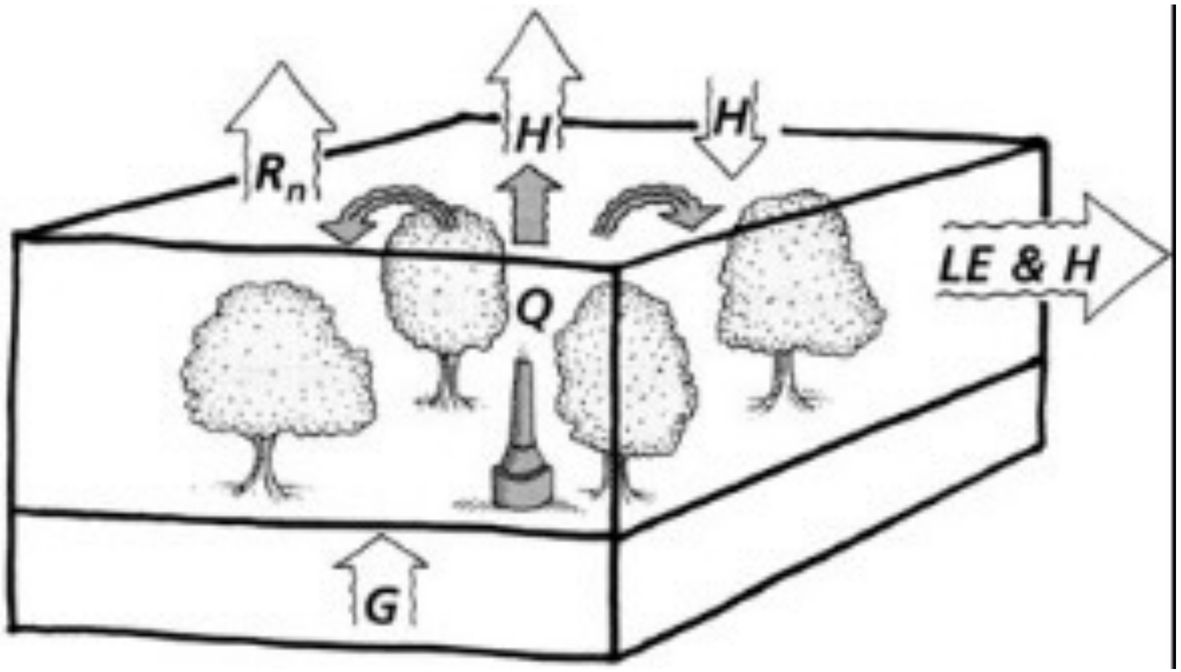
FROST DAMAGE: Cell injury

- Direct frost damage occurs when ice crystals form inside the protoplasm of cells (*severe intracellular freezing*)

- Indirect damage can occur when ice forms inside the plants but outside of the cells (*common extracellular freezing*).

ACTIVE FROST PROTECTION METHODS

- Energy –and/or labor Intensive
- They rely on physical processes to:
  - Add heat
  - Mix warm air from inversion
  - Conserve heat



Snyder and de Melo-Abreu (2005)

ACTIVE FROST PROTECTION METHODS

Irrigation adds heat through water freezing

ENERGY EXCHANGE

Process	cal g^{-1}
Cooling from 68ºF to 32ºF (20ºC to 0ºC)	20
Freezing at 32ºF (0ºC)	80
Evaporation	-597

Snyder and de Melo-Abreu (2005)

IRRIGATION METHODS OF FROST PROTECTION

- Over- plant sprinklers
  - Conventional rotating
  - Variable rate sprinklers
  - Low-volume (targeted) sprinklers
- Under-plant Sprinklers
- Surface irrigation
- Artificial fog
- Combination methods

Snyder and de Melo-Abreu (2005)

SPRINKLERS

Advantages

- Low energy consumption
- Low operational costs
- Low Labor requirements

Disadvantages

- High installation costs
- High water requirements

Additional Concerns

- Water logging of soils
- Nutrient leaching
- Erosion
- Environmental impacts

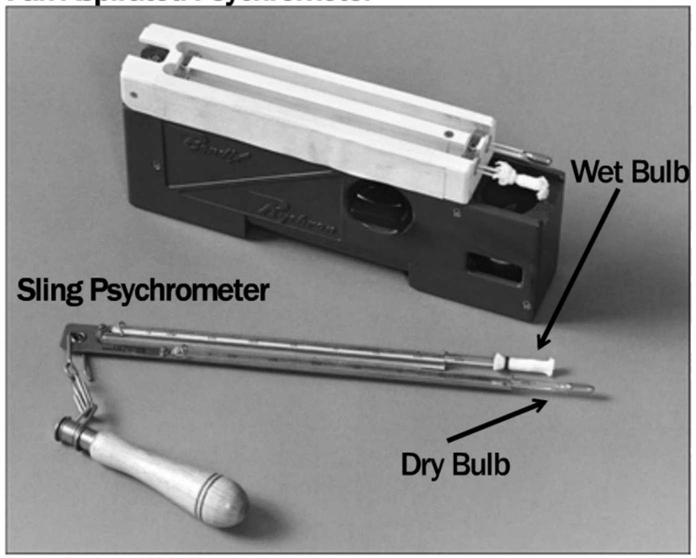
Snyder and de Melo-Abreu (2005)

OVER-PLANT SPRINKLERS

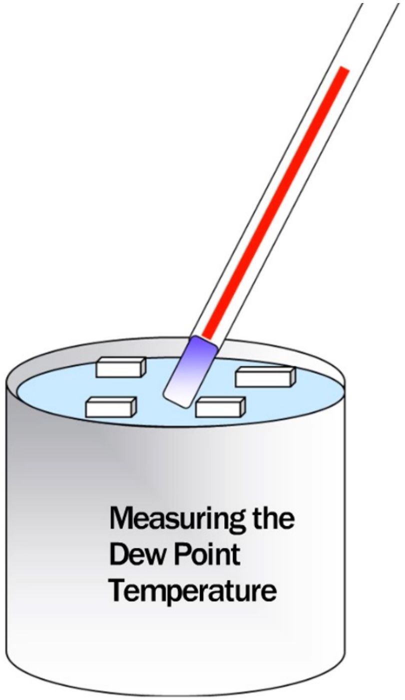
- Re-apply water frequently at a sufficient rate
- They can have efficient protection even under advection frosts events
- Windy conditions drive Evaporation and can be more damaging if water application is not sufficient
- Liquid ice-water mixture with dripping water is a sign of good application rate for the protection
- Sprinkler distribution uniformity is critical
- Recommended mounting ~ 1 ft above the canopy

Snyder and de Melo-Abreu (2005)

DECIDING ON STARTING/STOPPING THE SPRINKLERS



Source: Snyder and Melo-Abreu



- Starting before wet bulb temp drops below critical temp (even on a sunny day)
- Milky white ice appearance might be a sign of not enough protection

Snyder and de Melo-Abreu (2005)

DECIDING ON STARTING/STOPPING THE SPRINKLERS

Dew-point Temperature	Wet-bulb Temperature (°F)										
°F	22	23	24	25	26	27	28	29	30	31	32
32											32.0
31										31.0	32.7
30									30.0	31.7	33.3
29								29.0	30.6	32.3	34.0
28							28.0	29.6	31.2	32.9	34.6
27						27.0	28.6	30.2	31.8	33.5	35.2
26					26.0	27.6	29.2	30.8	32.4	34.0	35.7
25				25.0	26.5	28.1	29.7	31.3	32.9	34.6	36.3
24			24.0	25.5	27.1	28.6	30.2	31.8	33.5	35.1	36.8
23		23.0	24.5	26.0	27.6	29.1	30.7	32.3	34.0	35.6	37.3
22	22.0	23.5	25.0	26.5	28.1	29.6	31.2	32.8	34.5	36.1	37.8
21	22.5	24.0	25.5	27.0	28.5	30.1	31.7	33.3	34.9	36.6	38.2
20	22.9	24.4	25.9	27.4	29.0	30.6	32.1	33.7	35.4	37.0	38.7
19	23.4	24.9	26.4	27.9	29.4	31.0	32.6	34.2	35.8	37.5	39.1
18	23.8	25.3	26.8	28.3	29.8	31.4	33.0	34.6	36.2	37.9	39.5

OVERHEAD IRRIGATION APPLICATION FOR COOLING

- The onset of vegetation development in the spring increases the risk of cold damage

- The application of water can be used to lower the ambient temperature and plant tissue during latent heat loss to evaporation

- It has been shown that lowering the temperatures in this way delays phenological development.

- This is an important frost prevention method to be considered, given the limitations that many active frost protection methods have.

FORECASTING AND MONITORING

- Empirical forecast model for minimum temperatures, that can easily be calibrated for local conditions, is available (FFST.xls)

- It is useful for radiation frost events in areas with limited cold air drainage

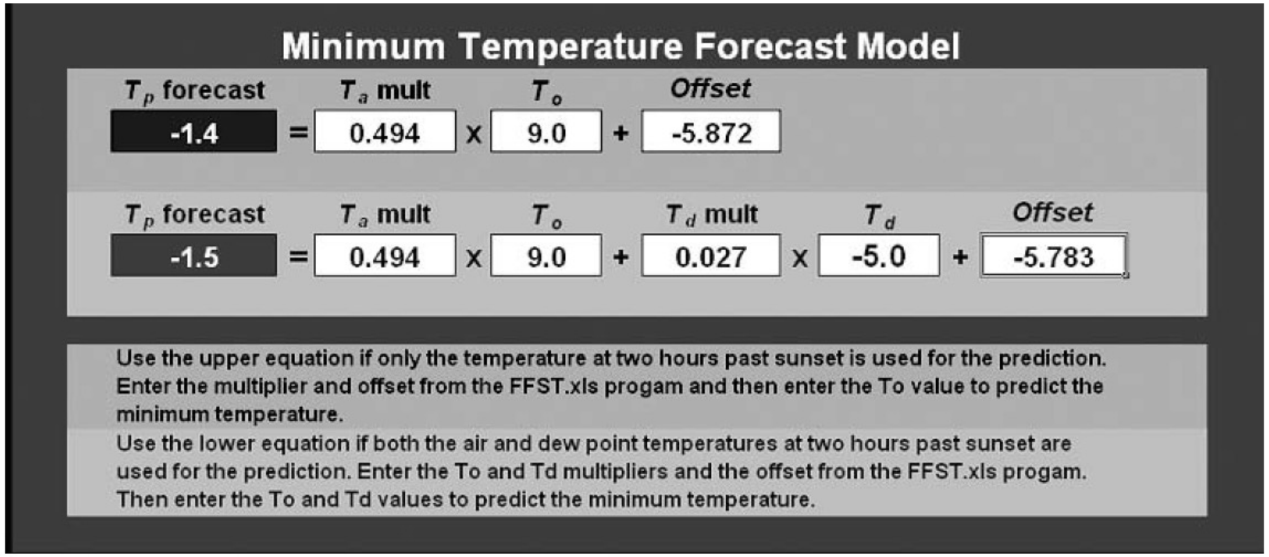
RMSE (°C)	Equation
0.65	$T_p' = 0.494 \times T_o + -5.874$
0.64	$T_p = 0.494 \times T_o + 0.027 \times T_d + -5.784$

Sample number	Observations at two (2) hours after sunset: Temperature T_o (°C)	Dew point T_d (°C)	Observed minimum Temperature T_n (°C)	Prediction from Temperature T_p' (°C)	Residual $R_1 = T_n - T_p'$	Residual from Dew Point R_1'	Predicted minimum Temperature T_p (°C)	Residual Temperature $T_n - T_p$ (°C)
1	3.2	-4.2	-3.1	-4.3	1.2	0.0	-4.3	1.2
2	0.8	-8.8	-5.0	-5.5	0.5	-0.2	-5.6	0.7
3	0.2	-6.5	-6.3	-5.8	-0.5	-0.1	-5.9	-0.4
4	2.6	-6.2	-5.4	-4.6	-0.9	-0.1	-4.7	-0.8
5	4.4	-6.1	-4.0	-3.7	-0.3	-0.1	-3.8	-0.2
6	5.2	2.6	-2.5	-3.3	0.8	0.2	-3.2	0.6
7	2.7	-0.7	-4.8	-4.5	-0.3	0.1	-4.5	-0.4
8	1.2	-1.7	-5.0	-5.3	0.4	0.0	-5.3	0.3
9	4.5	-1.2	-4.4	-3.7	-0.7	0.1	-3.6	-0.8
10	5.6	0.1	-3.3	-3.1	-0.2	0.1	-3.0	-0.2
11								
12								

Snyder and de Melo-Abreu (2005)

FORECASTING AND MONITORING

- Application model for predicting trends of temperature from 2 hours past sunset until the daily minimum right before sunset (FTrend.xls)
- This is helpful information to decide when to start and stop active protection

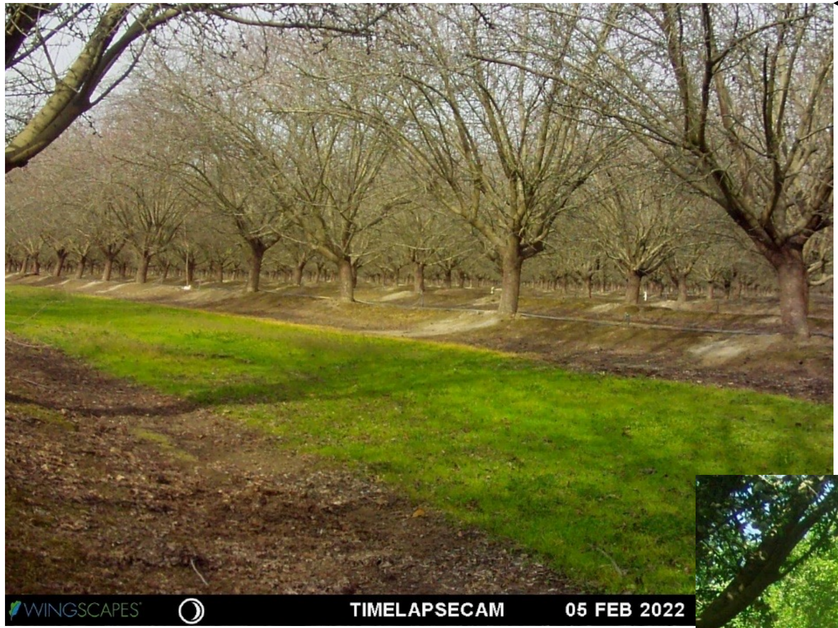


Snyder and de Melo-Abreu (2005)

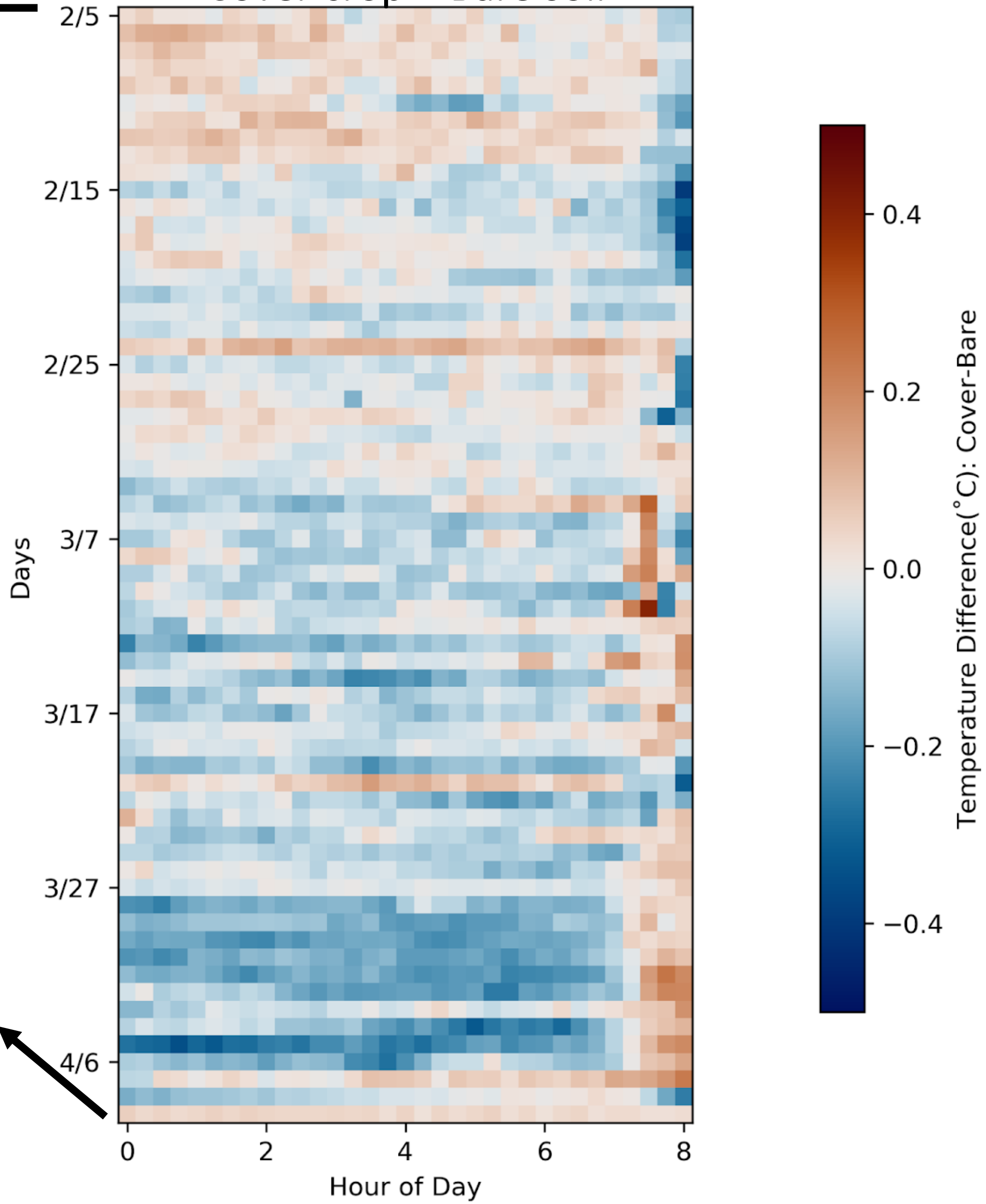
- Although good forecasting is important to decide if and when to start active protection, on site monitoring is even more beneficial.

Measuring winter air temperatures as influenced by a cover crop in an almond orchard (Chowchila, CA)

Three trees in each plot (★) were outfitted with three Hobo Pendant temperature sensors (like hanging Christmas tree ornaments)

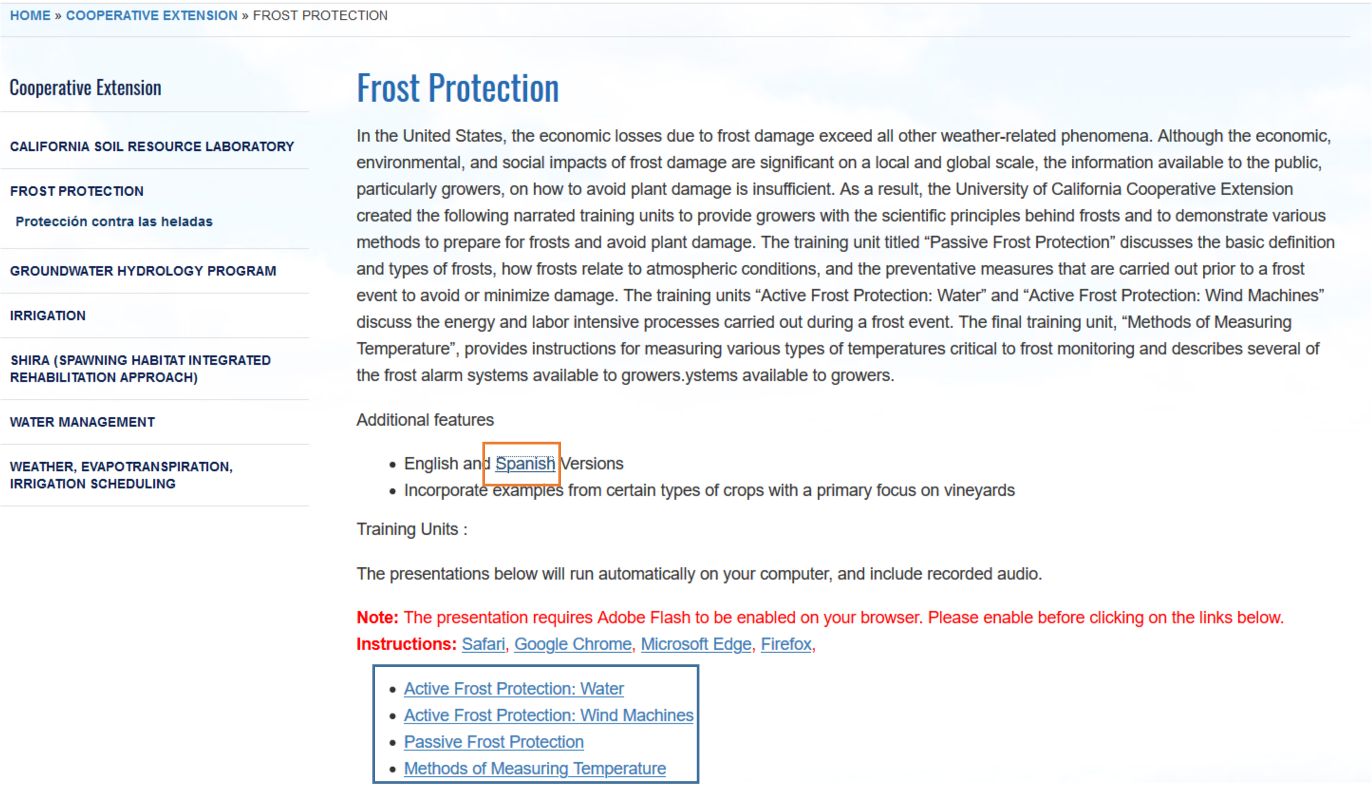


Nighttime
Temperature differences
Cover crop – Bare soil



UC Davis Frost protection resources:

- http://lawr.ucdavis.edu/cooperative-extension/frost-protection


HOME » COOPERATIVE EXTENSION » FROST PROTECTION

Cooperative Extension

- CALIFORNIA SOIL RESOURCE LABORATORY
- FROST PROTECTION
  - Protección contra las heladas
- GROUNDWATER HYDROLOGY PROGRAM
- IRRIGATION
- SHIRA (SPAWNING HABITAT INTEGRATED REHABILITATION APPROACH)
- WATER MANAGEMENT
- WEATHER, EVAPOTRANSPIRATION, IRRIGATION SCHEDULING

Frost Protection

In the United States, the economic losses due to frost damage exceed all other weather-related phenomena. Although the economic, environmental, and social impacts of frost damage are significant on a local and global scale, the information available to the public, particularly growers, on how to avoid plant damage is insufficient. As a result, the University of California Cooperative Extension created the following narrated training units to provide growers with the scientific principles behind frosts and to demonstrate various methods to prepare for frosts and avoid plant damage. The training unit titled "Passive Frost Protection" discusses the basic definition and types of frosts, how frosts relate to atmospheric conditions, and the preventative measures that are carried out prior to a frost event to avoid or minimize damage. The training units "Active Frost Protection: Water" and "Active Frost Protection: Wind Machines" discuss the energy and labor intensive processes carried out during a frost event. The final training unit, "Methods of Measuring Temperature", provides instructions for measuring various types of temperatures critical to frost monitoring and describes several of the frost alarm systems available to growers.ystems available to growers.

Additional features

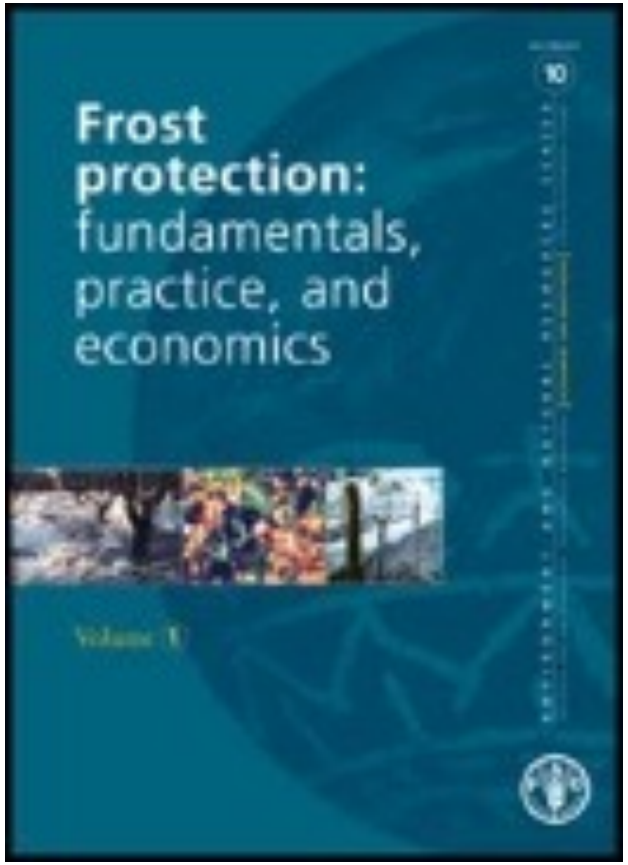
- English and Spanish Versions
- Incorporate examples from certain types of crops with a primary focus on vineyards

Training Units :

The presentations below will run automatically on your computer, and include recorded audio.

Note: The presentation requires Adobe Flash to be enabled on your browser. Please enable before clicking on the links below.
Instructions: Safari, Google Chrome, Microsoft Edge, Firefox,

- Active Frost Protection: Water
- Active Frost Protection: Wind Machines
- Passive Frost Protection
- Methods of Measuring Temperature



Thanks!
Questions?

¡Gracias!
¿Preguntas?

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