Frost Protection Considerations

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Presented with the assistance of…

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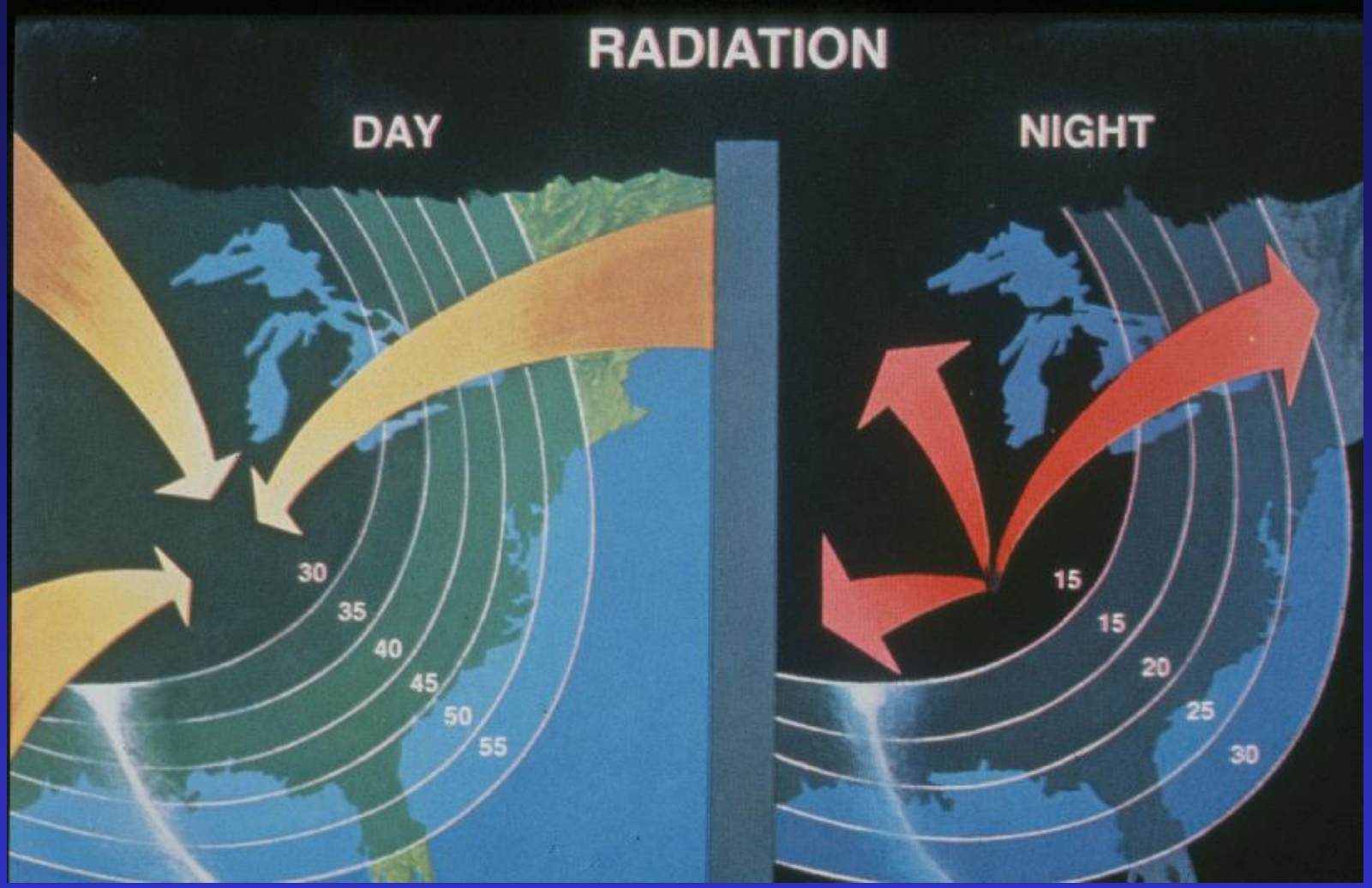
- http://biomet.ucdavis.edu/
- Rhonda Smith, UC CE Farm Advisor, Sonoma County
- Rachel Elkins, UC CE Farm Advisor, Lake County
- Steve Lindow, UC Berkeley

To be covered….

- Radiation frosts versus Advective freezes
- Passive frost protection methods
- Active frost protection methods
- When to turn sprinklers on and off

Why Frost Protect?

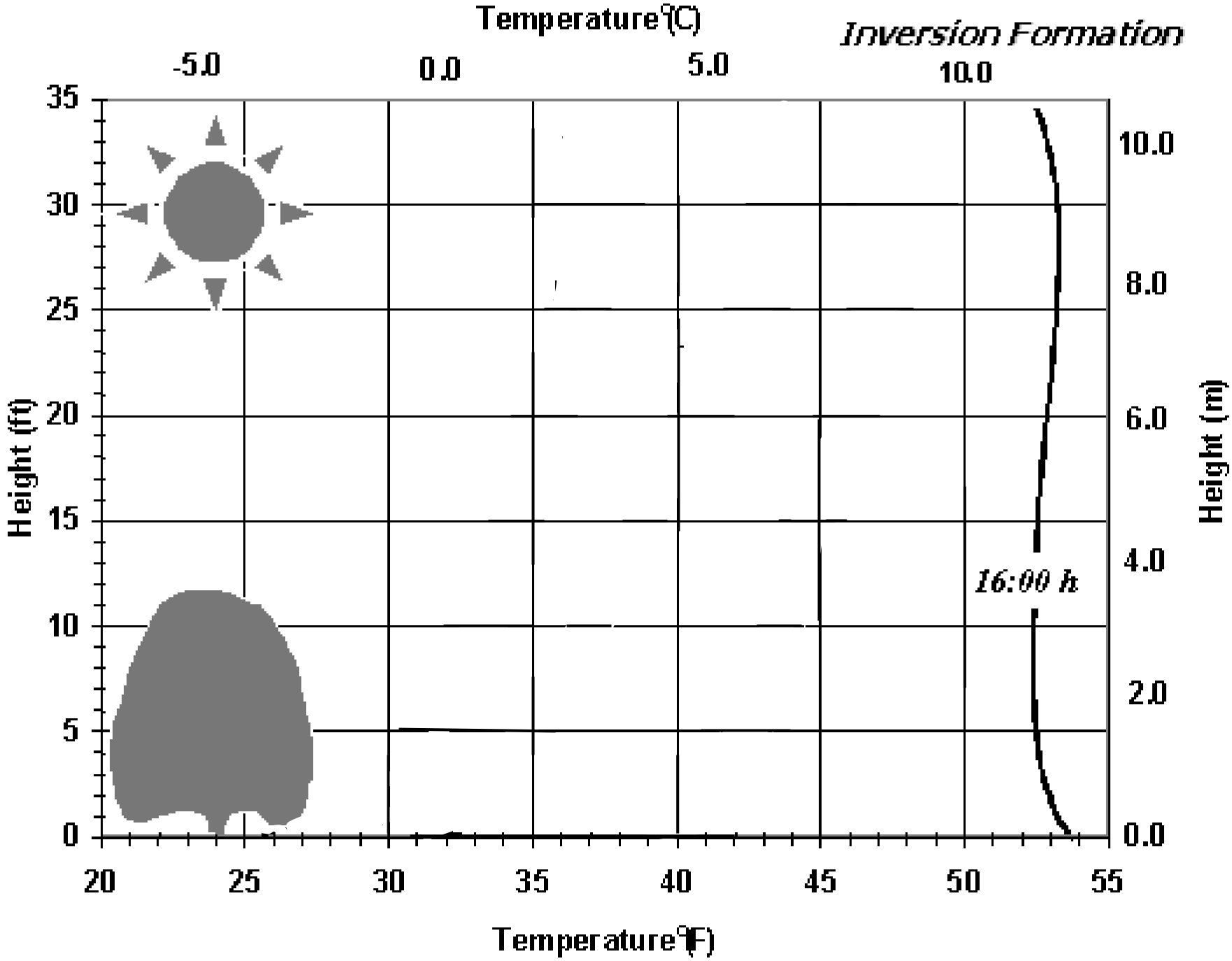
- All green parts of the vine are susceptible to frost, all during the growing season



More heat radiates AWAY from earth than it receives

Radiation Frost

- Occurs when nights are clear, and heat radiates from the earth
- Air is stratified, with coolest air close to the ground, and the air is usually still
- If warm air is 10-50 feet above the ground, it is possible to mix the air with fans
- These frost events are frequently mild, and usually above 27 °F


Temperature (C)
Inversion Formation
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5.0
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Height (ft)
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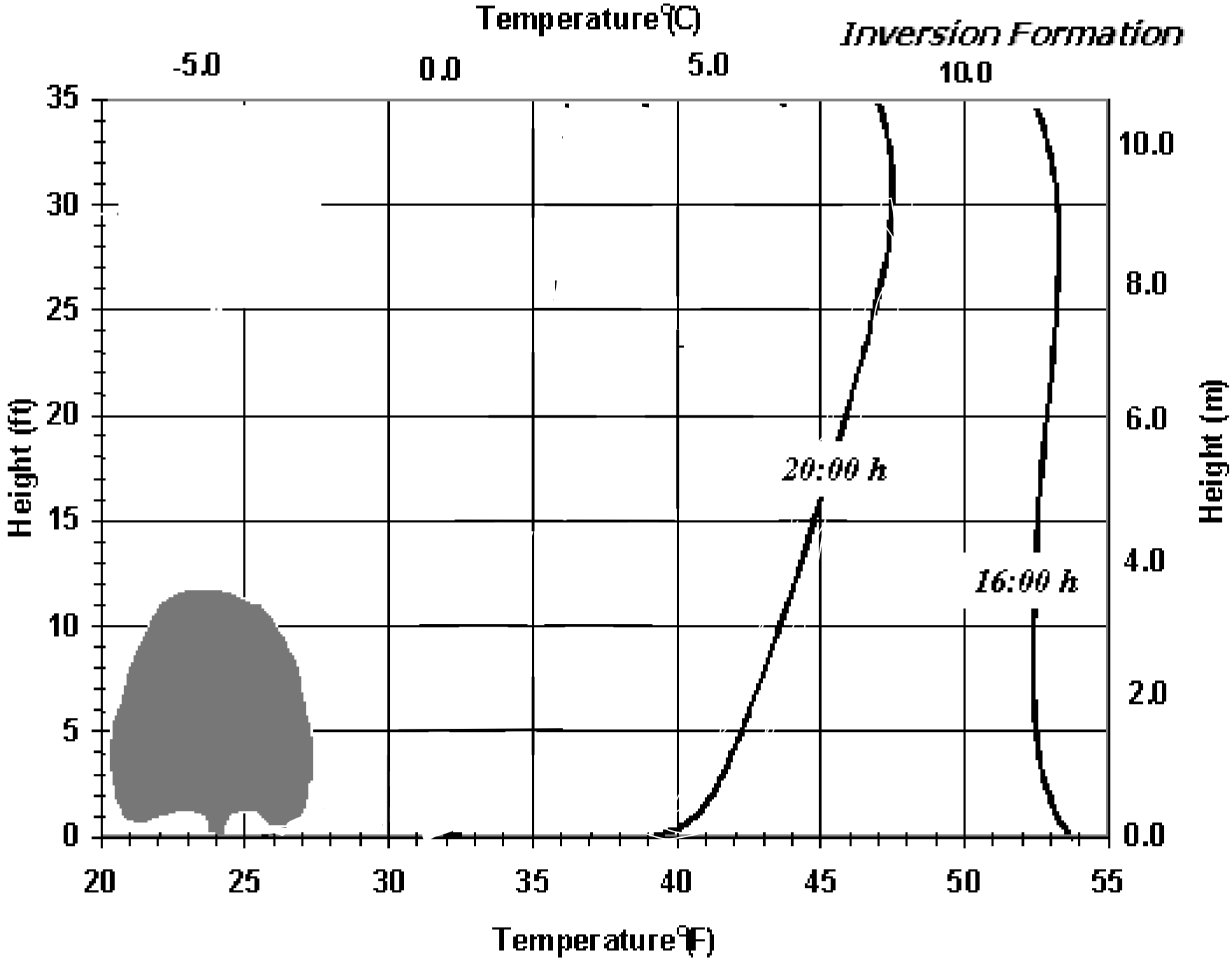
Temperature (F)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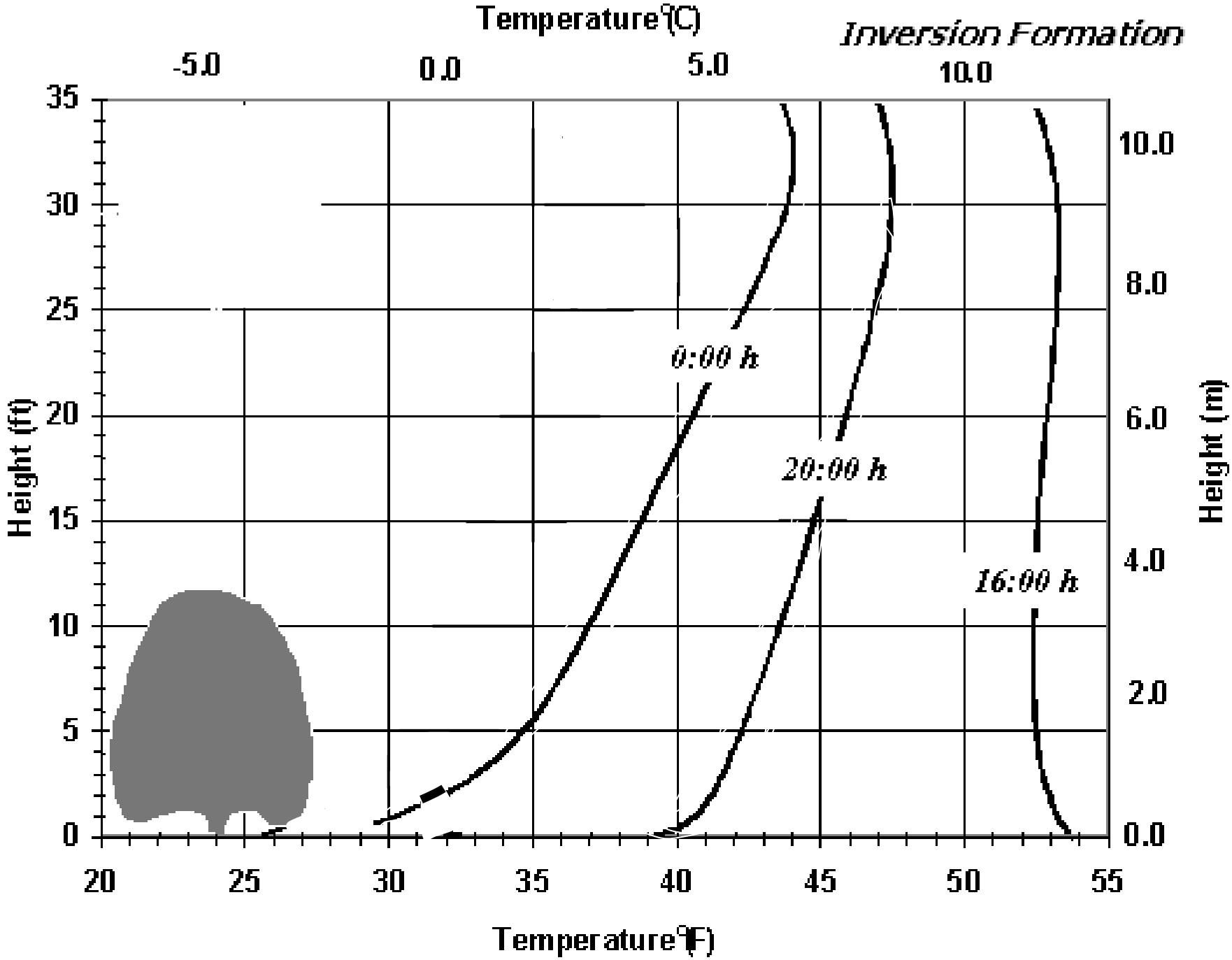
Temperature (F)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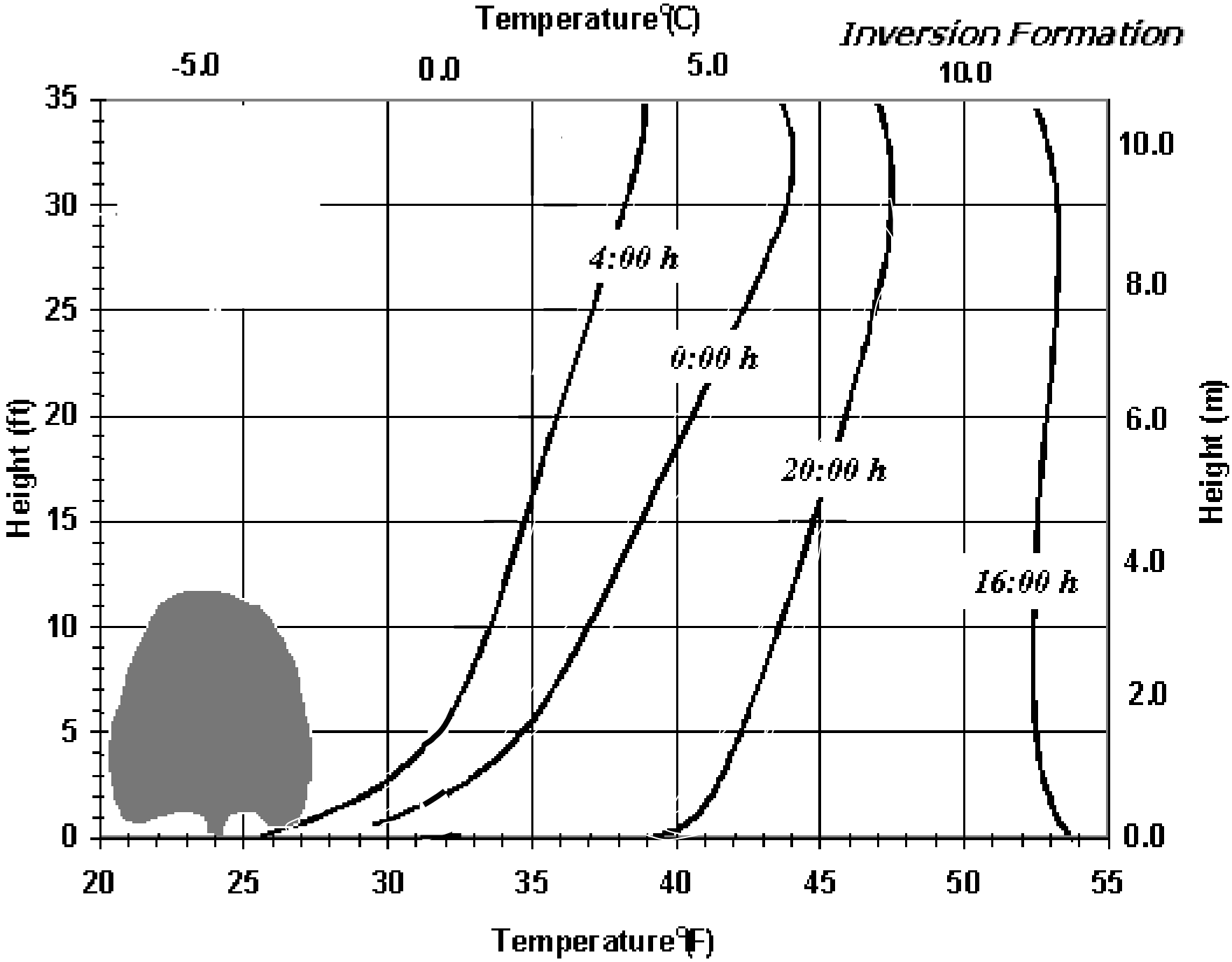
Temperature (F)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Height (m)
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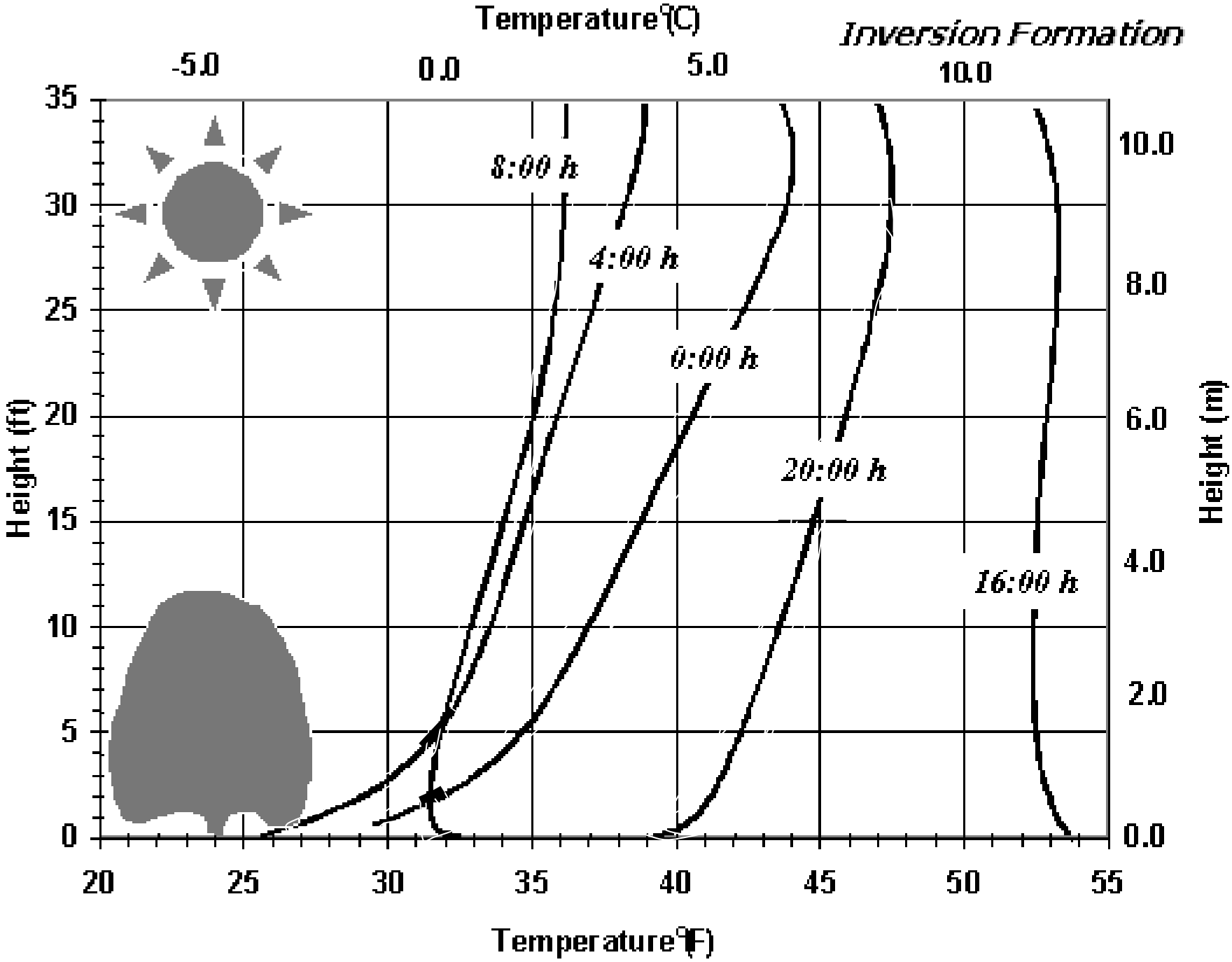
Temperature (F)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Height (ft)
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30
25
20
15
10
5
0
Height (m)
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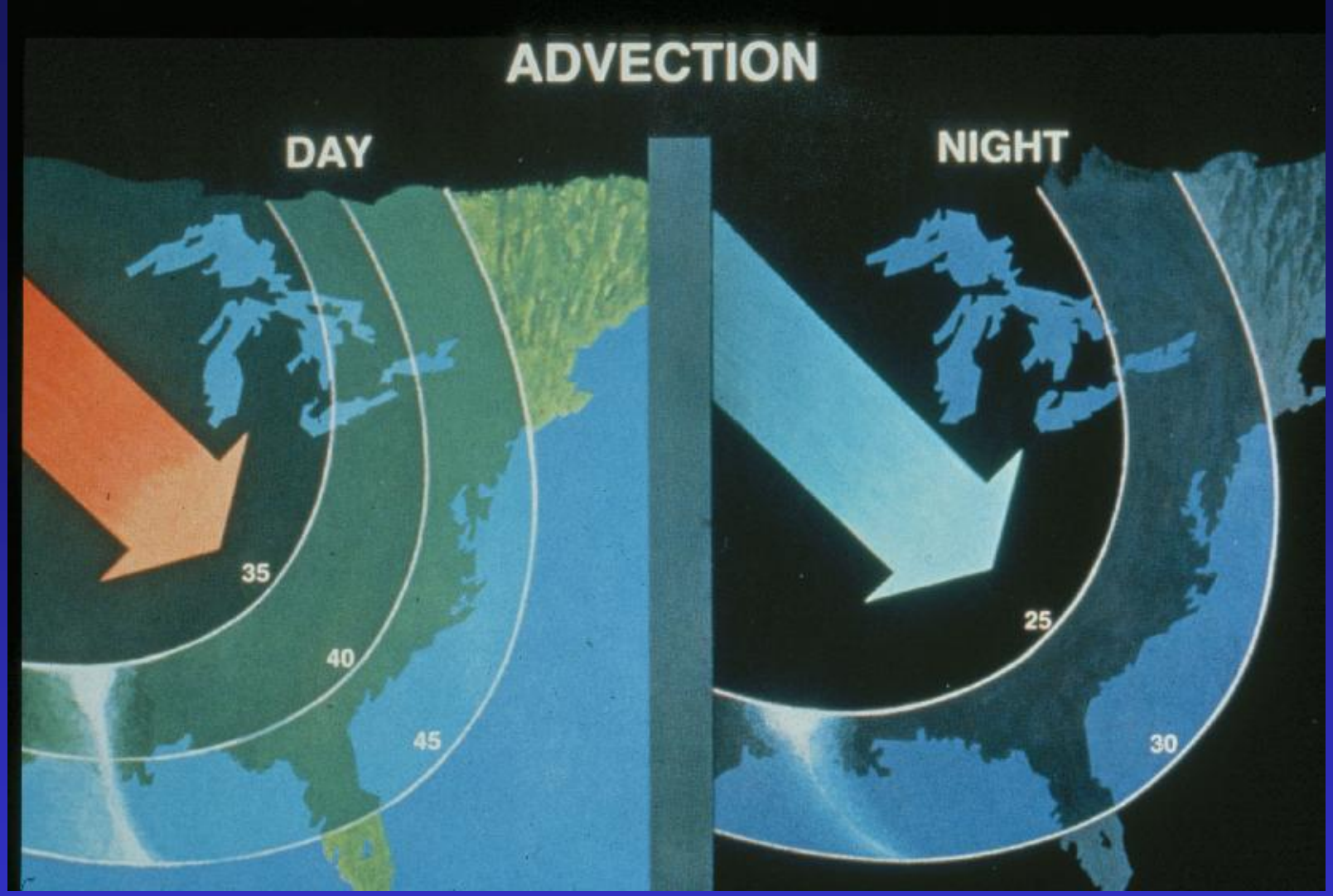
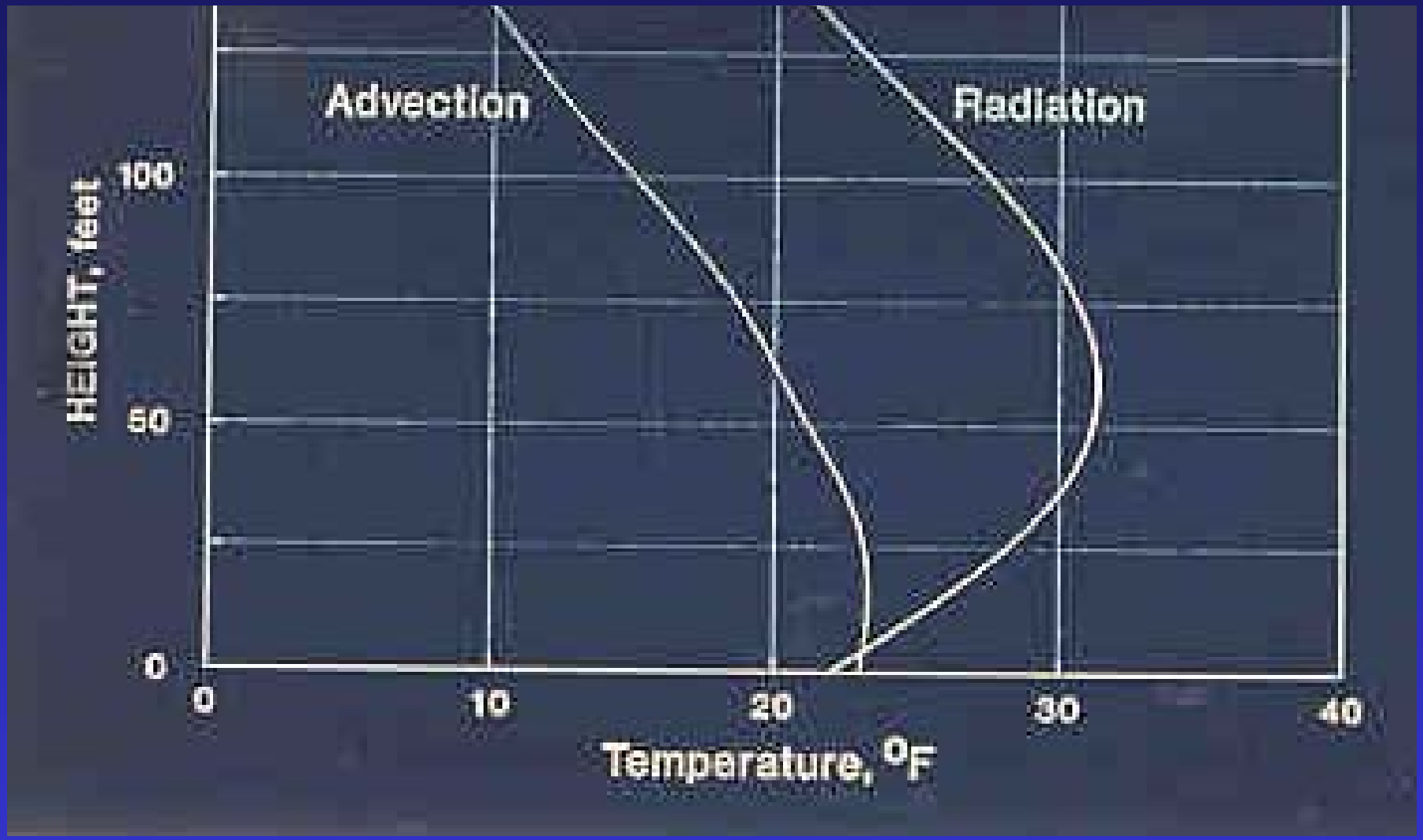
8.0
6.0
4.0
2.0
0.0
20
25
30
35
40
45
50
55
Temperature (F)

Advective Freeze

- This is caused by a large cold air mass, usually accompanied by wind and low humidity
- The air may actually become colder with elevation
- These freezes can be very cold, going down to 21 °F
- These can cause more damage than radiation frosts because active protection measures are not effective



Moderate to strong winds; no inversion; low relative humidity


Advection
Radiation
HEIGHT, feet
100
50
0
0
10
20
30
40
Temperature, °F

For radiation frosts only!

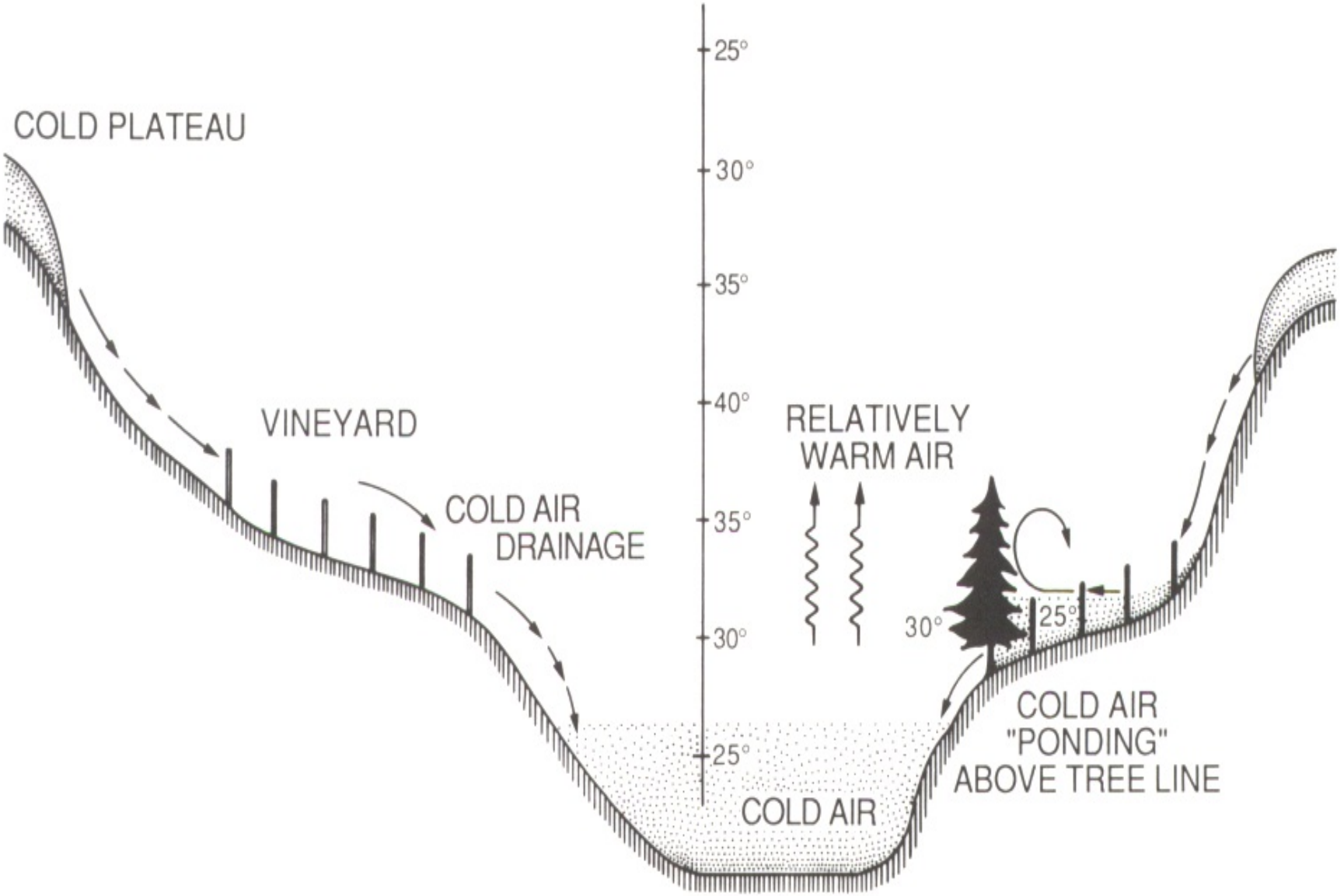
Passive Frost Protection Methods

- **Site selection**
- **Late vs. early varieties: Cool facing slopes for early varieties**
- **Soil water management**
- **Ground covers**
- **Time and method of pruning**

Site Selection

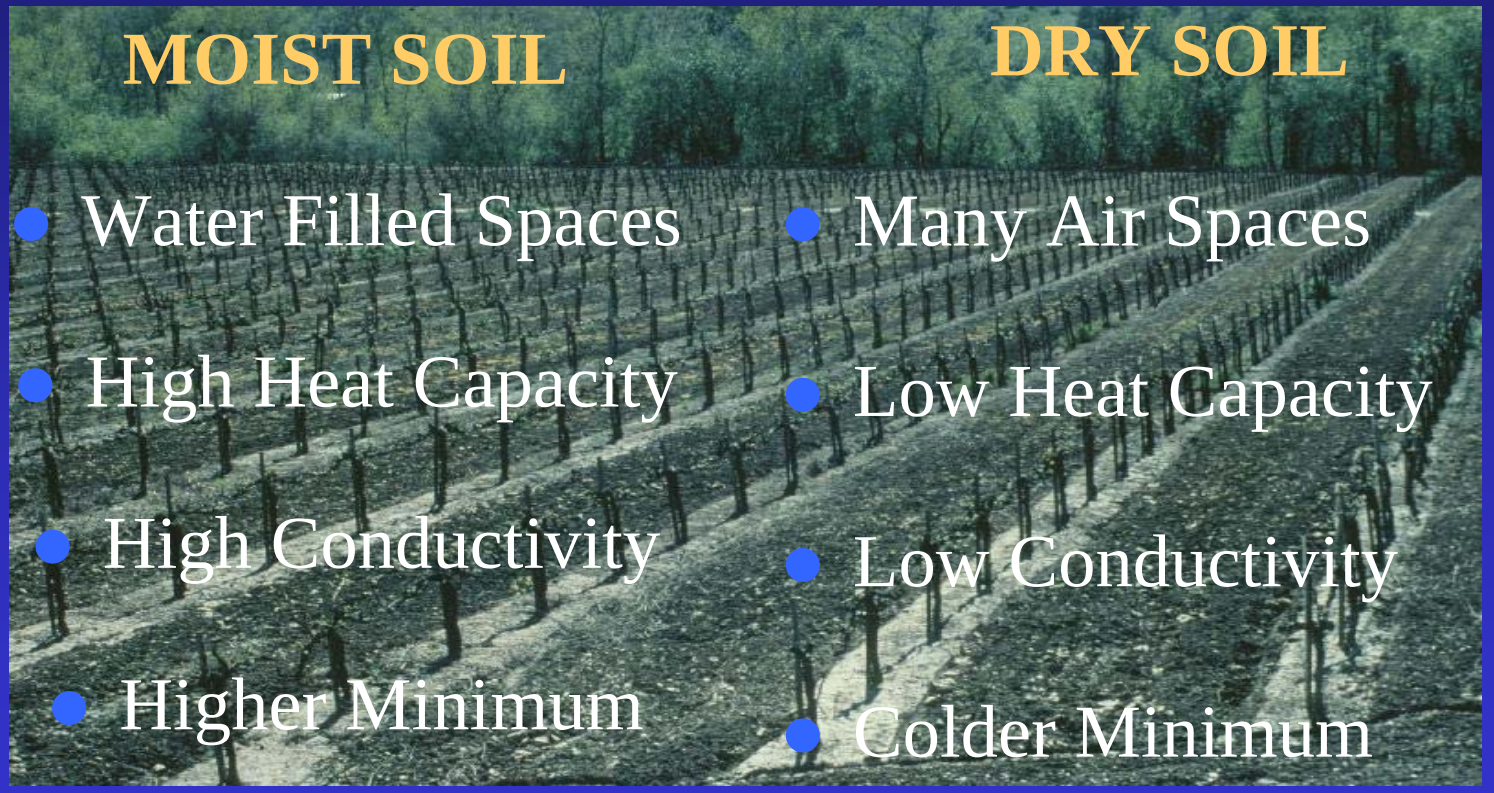
- **Old tradition of planting vineyards--upland areas are best if you have a choice**
- **South and West facing slopes tend to be warmest…*(but are they the safest for other concerns??)***
- **Manage brush, trees or other air dams that prevent cool air from flowing out of the vineyard**

Site Selection: Cold Air Flow



From "*Site Selection for Commercial Vineyards*", Pub. No. 463-016 Virginia Cooperative Extension

Soil Water Management



MOIST SOIL

- Water Filled Spaces
- High Heat Capacity
- High Conductivity
- Higher Minimum

DRY SOIL

- Many Air Spaces
- Low Heat Capacity
- Low Conductivity
- Colder Minimum

Soil Water Management

- **Keep soil water content near field capacity**
- **Wet 2-3 days early**
- **Wet entire surface**
- **Wet the top foot**

Soil Water Management
To Reduce Frost Risk

- Maximum protection: Bare, packed soil - either cultivated or sprayed with herbicides

- Drawbacks: Erosion risk, loss of soil organic matter, destruction of soil structure, poor footing for early spring spraying

Ground Cover

- Reflects Sunlight
- Evaporates Water
- Reduces Stored Soil Heat
- Colder Minimum
- Ice Nucleating Frost
- Prevents erosion, many other benefits

Frost and Vineyard Floor Management

Ground Preparation	Temperature Change
Bare, Firm, Moist Ground	Warmest
Shredded Cover, Moist	0.5 ºF cooler
Low Cover, Moist Ground	1 to 3 ºF cooler
Dry, Firm Ground	2 ºF cooler
Freshly disked, fluffy	2 to 3 ºF cooler
High cover crop	2 to 4 ºF cooler
High cover crop, restricted air drainage	6 to 8 ºF cooler

Wilbur Reil, Yolo & Solano Tree Crops Advisor, retired

Ice Nucleating Bacteria

- Pseudomonas syringae
- Erwinia herbicola
- Pseudomonas flourescens
- Pseudomonas viridiflava
- Xanthomonas campestris var. vesicatoria

Most of the data on the risks associated with ice nucleating bacteria being present on grass cover crops is from citrus and pears.

Ice Nucleating Bacteria

+ -

Ice Nucleating Bacteria

+ -

Compromise with cover crops

- Plant in every other row with a ground cover
- Avoid species like bell beans and peas that cannot be mowed closely during frost period - or else disk in, mow short
- Mow everything early, before bud emergence (as much as 2 weeks ahead of time)
- If over head sprinklers used as frost protection, then growing cover crops in a frost prone regions becomes much safer


Double Pruning

Sprays

- Frostban (A506)
- Frost Shield
- Copper Compounds

Probably only copper is truly effective, and it would be best focused on the cover crops, since they produce the most bacteria (but any Cu in runoff can be very toxic to fish)

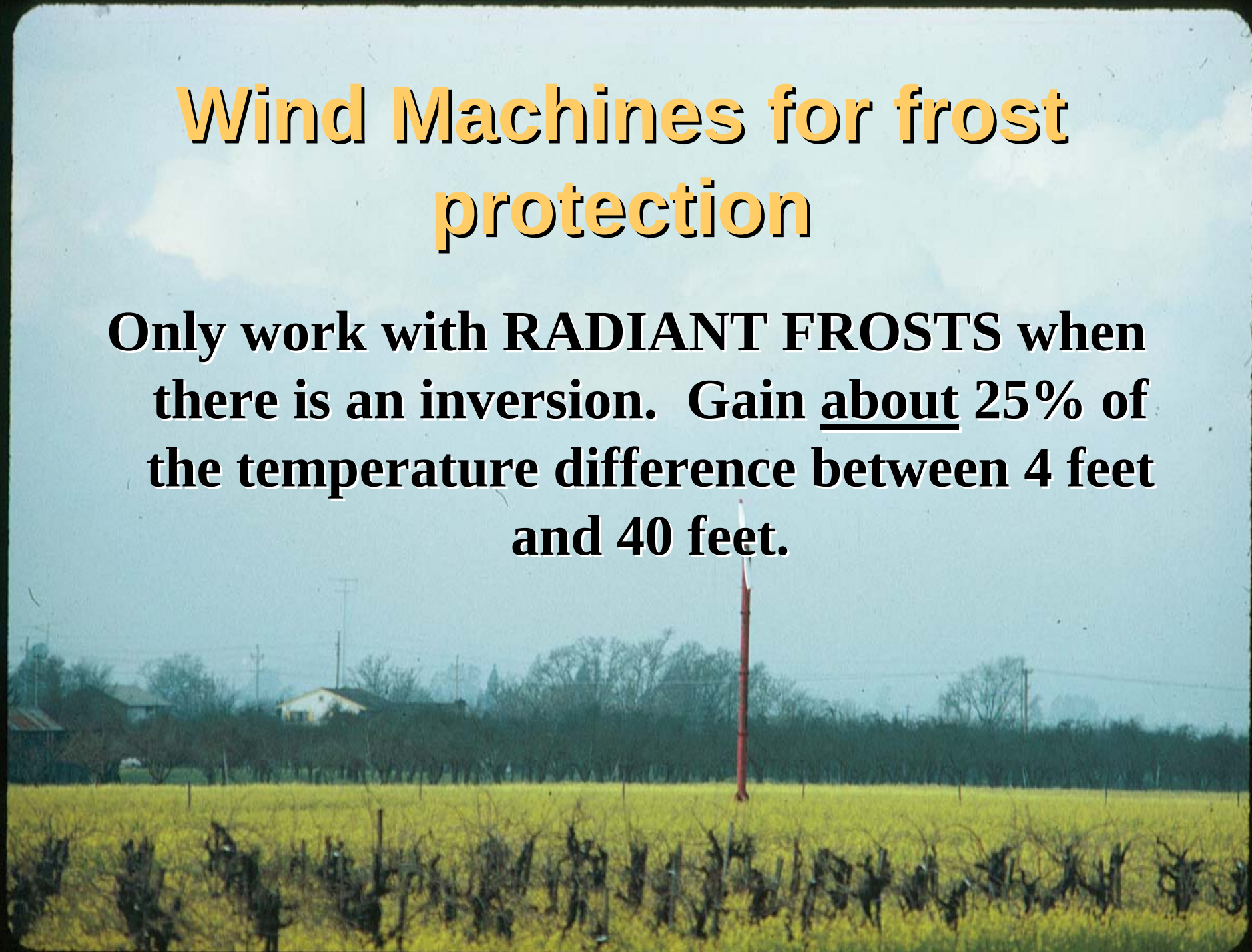
For radiation frosts only

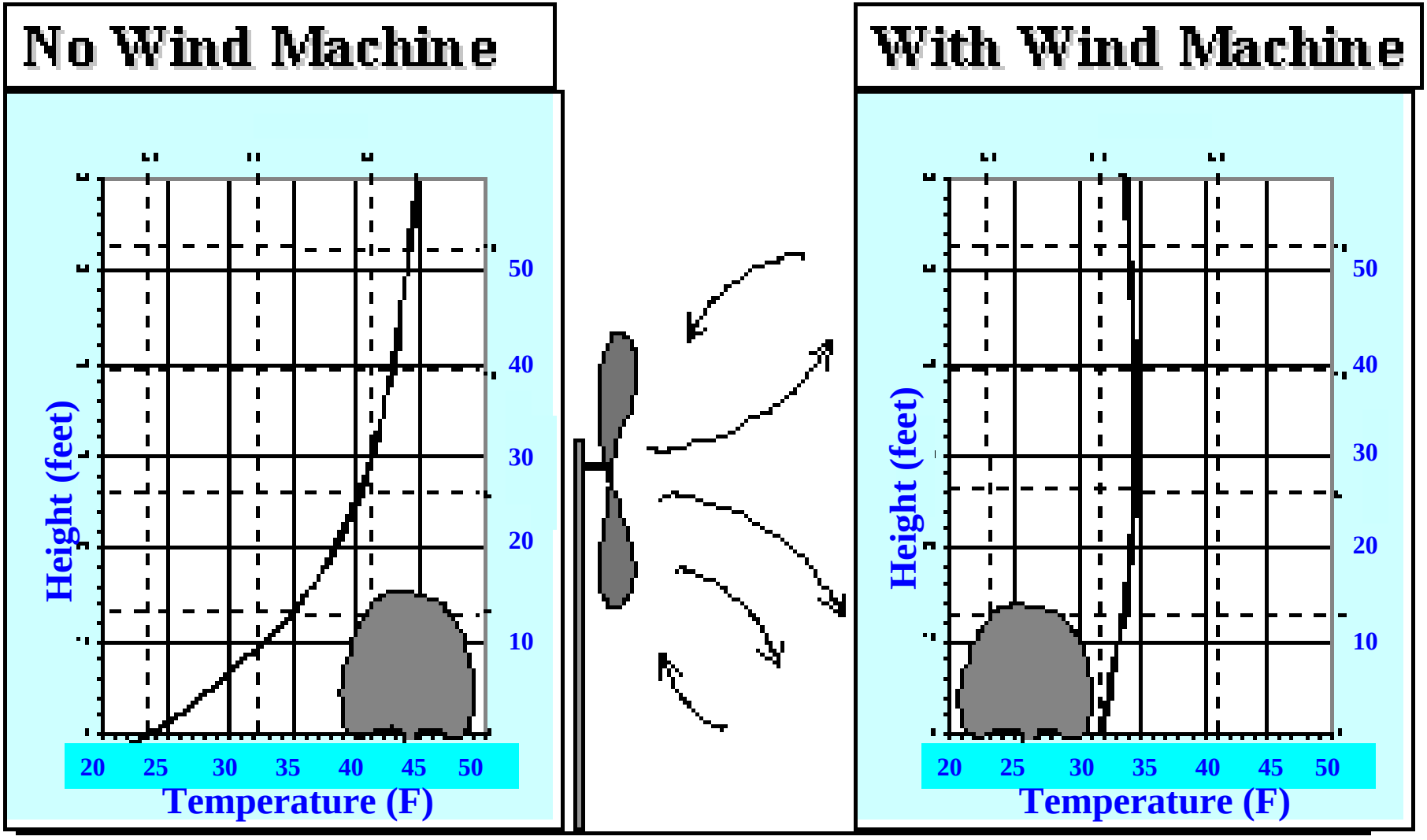
Active Frost Protection Methods

- **Wind Machines**
- **Orchard Heaters**
- **Overhead sprinklers**
- **Micro-sprinklers**

Wind Machines for frost protection

Only work with RADIANT FROSTS when there is an inversion. Gain about 25% of the temperature difference between 4 feet and 40 feet.





From *Principles of Frost Protection*, R. Snyder, UCD

Wind Machines

- **Turn on fans when the temperature at 5 foot height is above the critical damage temperature.**

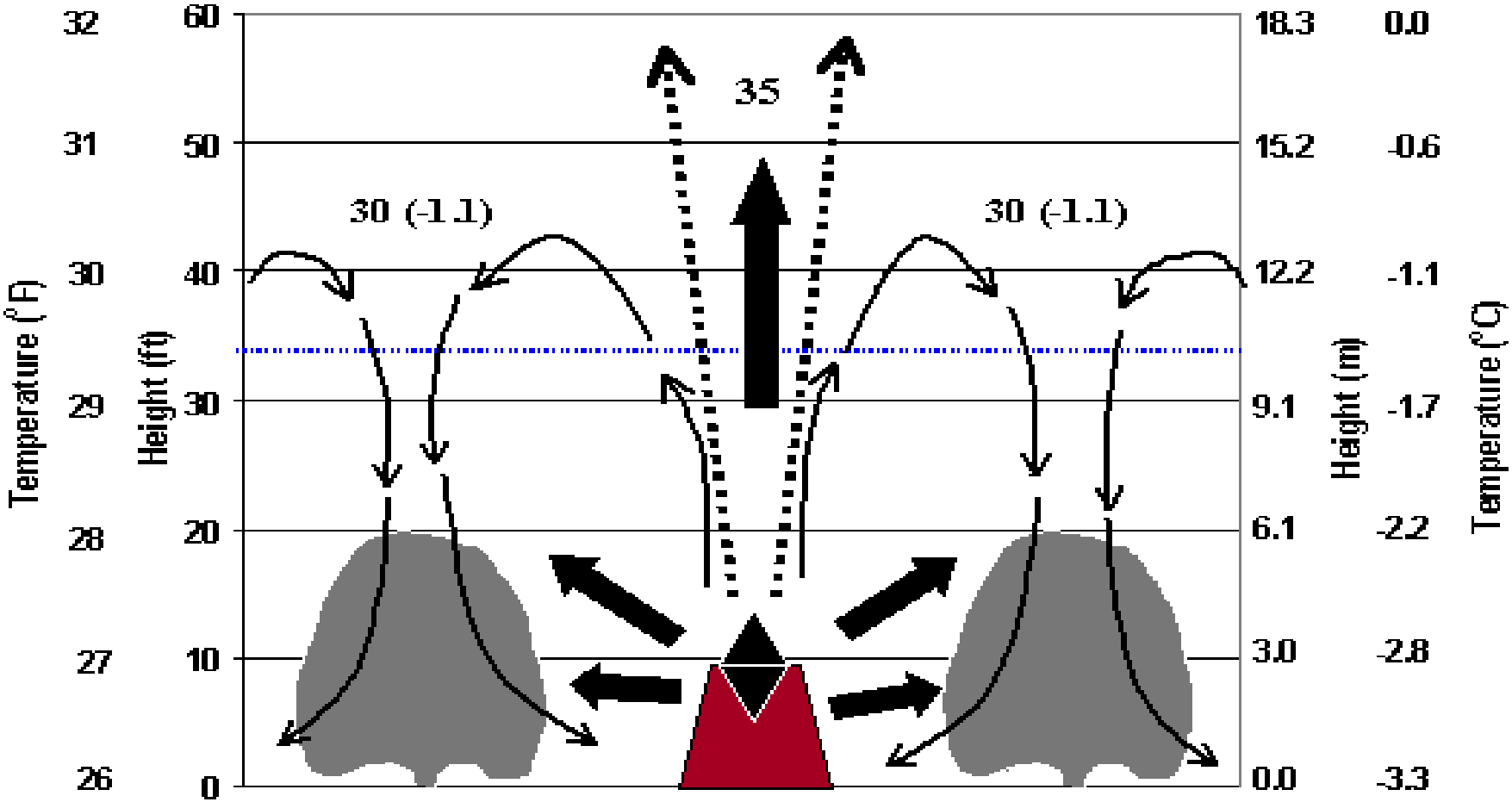
OR

- **Turn on fans before the temperature at 5 foot height falls much below the temperature at 33 foot height.**

Orchard heaters increase the effectiveness of wind machines

20-25 heaters/acre plus wind ⏩ 3 to 4 degree rise

Heaters



Heaters provide convective mixing of air. Work best with an inversion.

From *Principles of Frost Protection*, R. Snyder, UCD

Sprinkler Frost Protection

- The object is to maintain an ice/water interface around the green tissue
- When the water freezes, heat is liberated from the water, and a temperature of **32** °F is maintained as long as there is a mixture of water and ice with water dripping off the plants.

Sprinkler Requirements

Conventional pulsing sprinklers

- Uniform application of water
- Precipitation rate of 0.11 inches/ hour
- Equivalent of ***about*** 50 gallons per minute per acre
- Good pressure is needed (most systems > 50 psi)

Sprinkler Requirements

Conventional pulsing sprinklers

You Need Serious Water

When to turn on & off sprinklers

Definitions

- **Dry bulb temperature** = air temperature measured with a thermometer
- **Wet bulb temperature** = air temperature that occurs when heat is removed from the air to evaporate water until the air becomes saturated. Measured with a psychrometer OR calculated from DEW POINT and air temperature
- **Critical temperature** = the dry bulb temperature at which the crop begins to be damaged

Dew Point temperature

The dew point temperature is the air temperature when the air has reached 100% relative humidity. It assumes that water vapor content does not change. At the dew point temperature, water vapor in the air is likely to condense on surfaces as dew (or frost).

The dew point temperature can be measured or estimated from air temperature and relative humidity or from dry and wet-bulb temperatures. The weather service often reports the dew point temperature.

Dew or Frost Formation?

A Dew Point of 45 ºF:

- **Dew** begins to form on vegetation or other objects exposed to a clear sky when the temperature drops to 45 degrees F

A Dew Point of 28 ºF:

- **White frost** will appear when the temperature drops to 28 degrees F!

A **“high”** dew point (above 35° F)

- Temperature fall during the night is slow and steady with few fluctuations

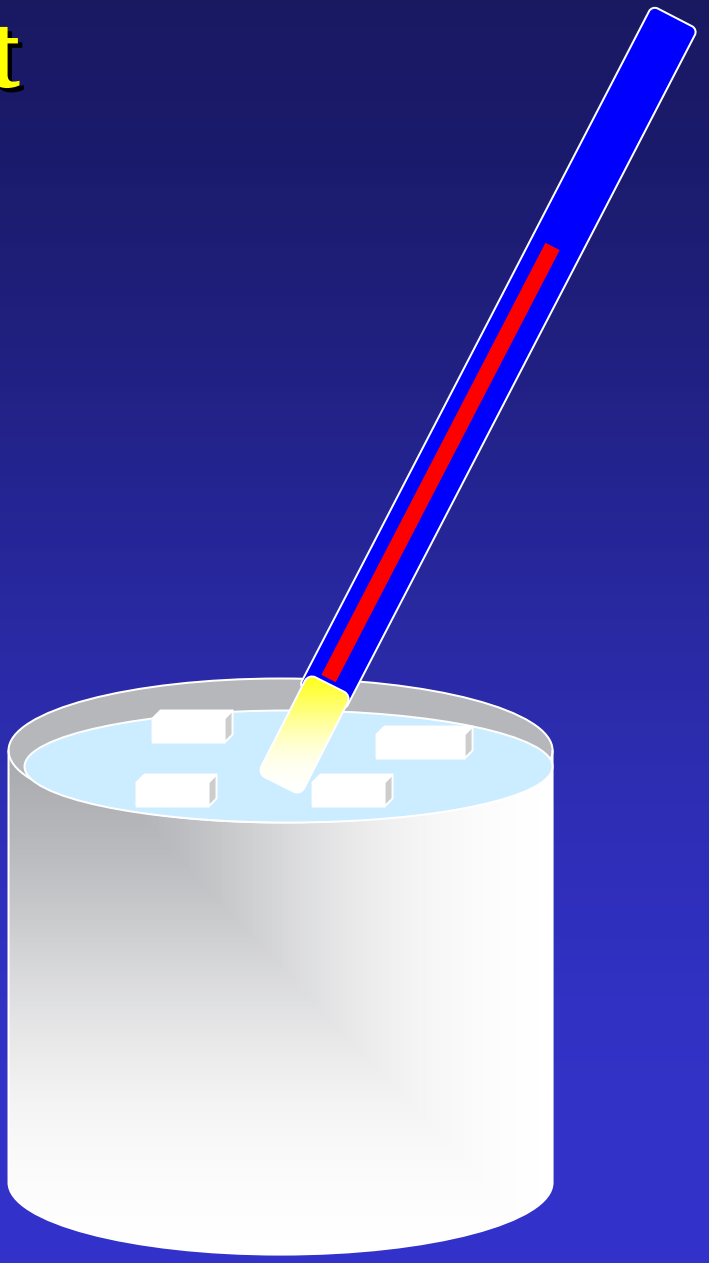
* Frost is rarely a problem when dew point is above 45° F.

A **“low”** dew point (below 25° F)

- Temperature fall is rapid
- Watch thermometers carefully
- Humidity is very low
- Frost damage is likely

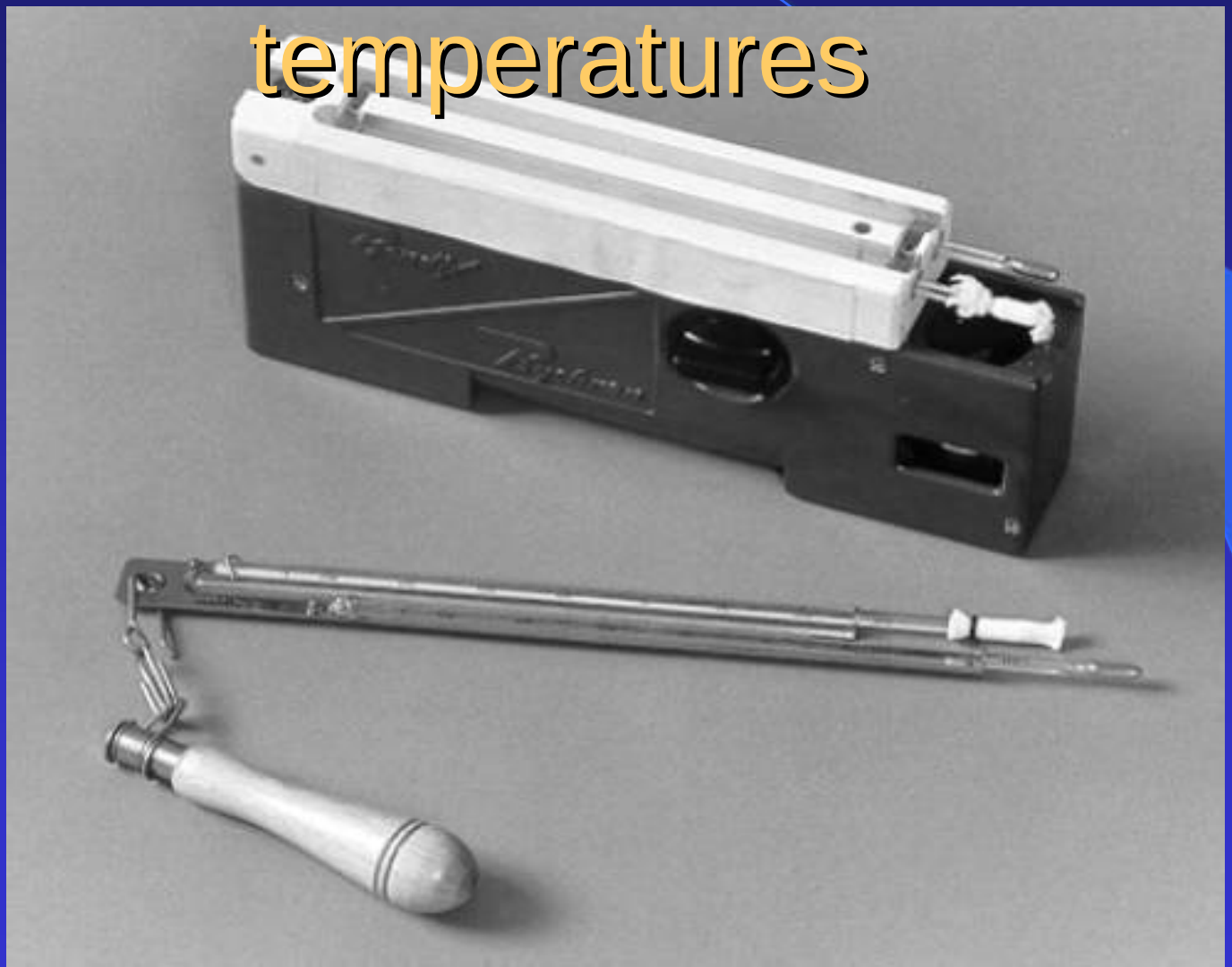
Measuring Dew point Temperature

Slowly add ice cubes to the water to lower the can temperature. Stir the water with a thermometer while adding the ice cubes to insure the same can and water temperature. When condensation occurs, note the dew point temperature.



From *Principles of Frost Protection*, R. Snyder, UCD

Find humidity with psychrometers: measure wet bulb and dry bulb temperatures



When to turn on & off sprinklers

Turn ON sprinklers

- When wet bulb is above the critical temperature. All sprinklers should be operating before the wet bulb temperature drops to the critical temperature upwind from the crop .

Turn OFF sprinklers

- When the sun is shining on the crop and the wet bulb temperature upwind of the crop is higher than the critical temperature. In practice, wait until 32ºF. But if it is windy or if dew point is low, don't turn off just because the air temp is $\geq$ 32°F. Wait until at least 34°F.

Use this table to figure out when to turn on overhead sprinklers

Wet Bulb Temperature

Dew Point temperature

Look up what the minimum air temperature must be for starting and stopping sprinklers

Choose a wet bulb temperature above the critical temperature, then find the air temperature corresponding to the wet bulb and dew point in the table.

Minimum TURN ON and OFF temperatures in ^{o}F for sprinkler frost protection

Dew Point Temperature, ^{o}F \ Wet-Bulb Temperature, ^{o}F	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	28.6	30.2	31.8	33.5	35.2
26	29.2	30.8	32.4	34.0	35.7
25	29.7	31.3	32.9	34.6	36.3
24	30.2	31.8	33.5	35.1	36.8

R. Snyder

When water is applied, temperatures fall then rise

GIVEN: When a sprinkler system is first started, the plant temperature might drop to the WET BULB temperature.

GOOD: Temperature then increases as water freezes.

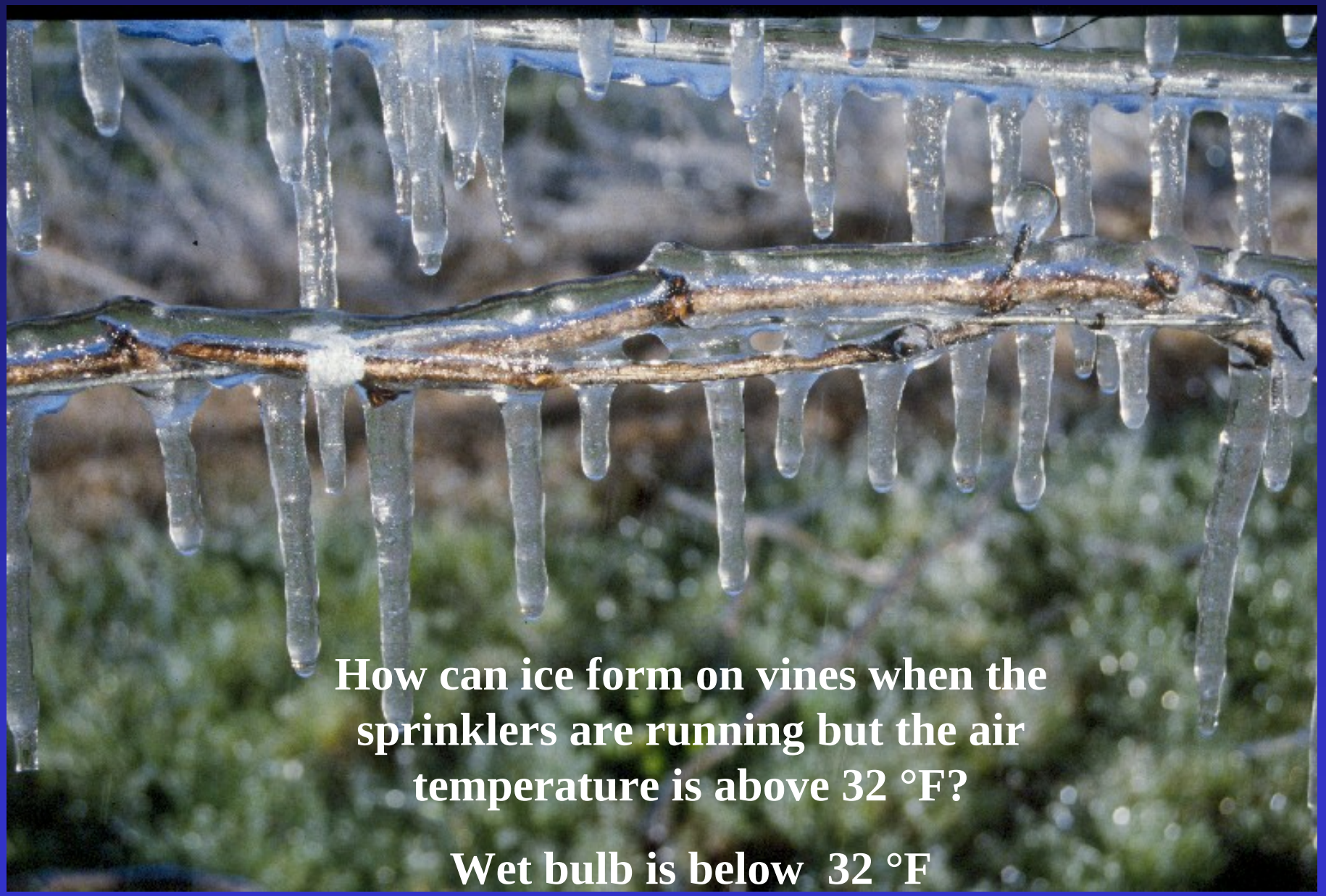
BAD: If the DEW POINT temperature is low, then the WET BULB is much lower then the air temperature and damage can occur if insufficient water is applied.

If the wet bulb temperature is **AT or BELOW** the critical temperature, then the air temperature can drop below the critical temperature and cause damage.

Beware of a Low Dew Point!

BASIC CONCEPT: Temperatures will drop lower when the air is dry. Turning on the sprinklers may initially bring the surface temperatures of the vines below the freezing point due to evaporative cooling.

WHAT TO DO: The drier the air, the sooner you must turn on the sprinklers


How can ice form on vines when the sprinklers are running but the air temperature is above 32 °F?
Wet bulb is below 32 °F

Pulsating microsprinklers

Features

- The only water frost protection system possible when there is little water available
- Can be operated from same well and pump as your drip system
- Will prevent damage at temperatures no less than 26 ºF ?????
- Horizontally divided systems will require 2 heads per vine.
- Much earlier turn on times than conventional sprinklers


Partial block protection


Thanks For Your Attention!
More Information:
http://biomet.ucdavis.edu