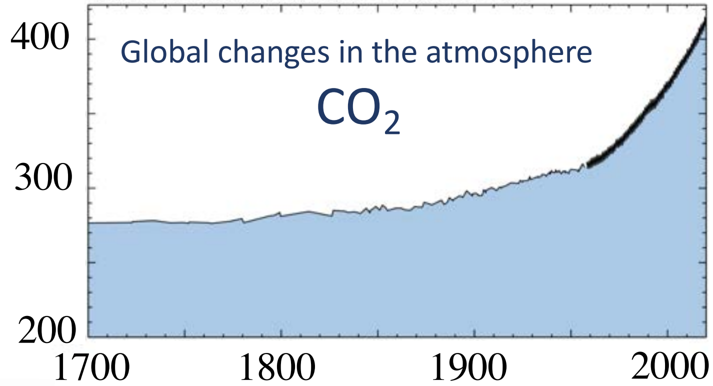


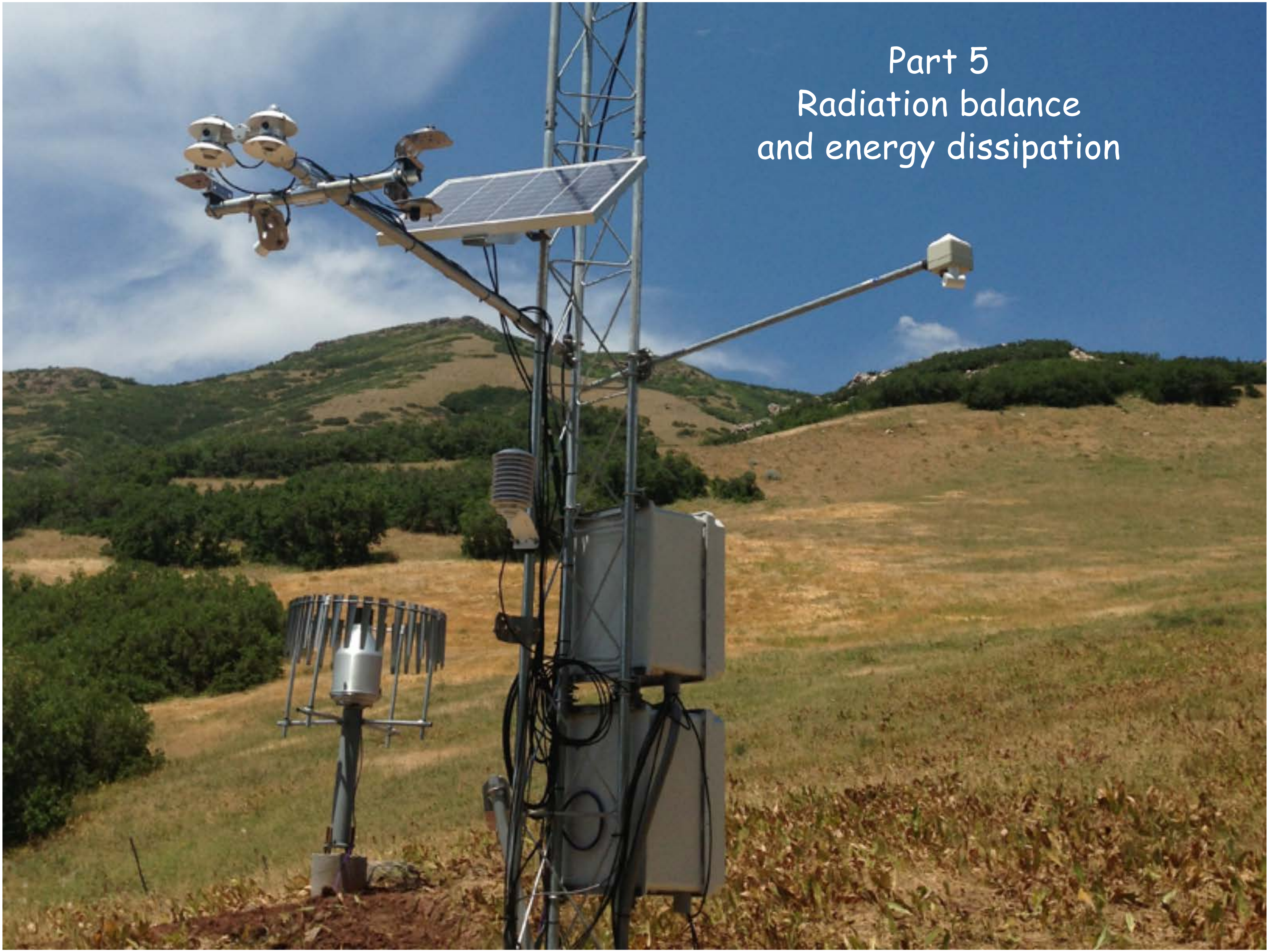
Topic 8

Macroclimates and Microclimates

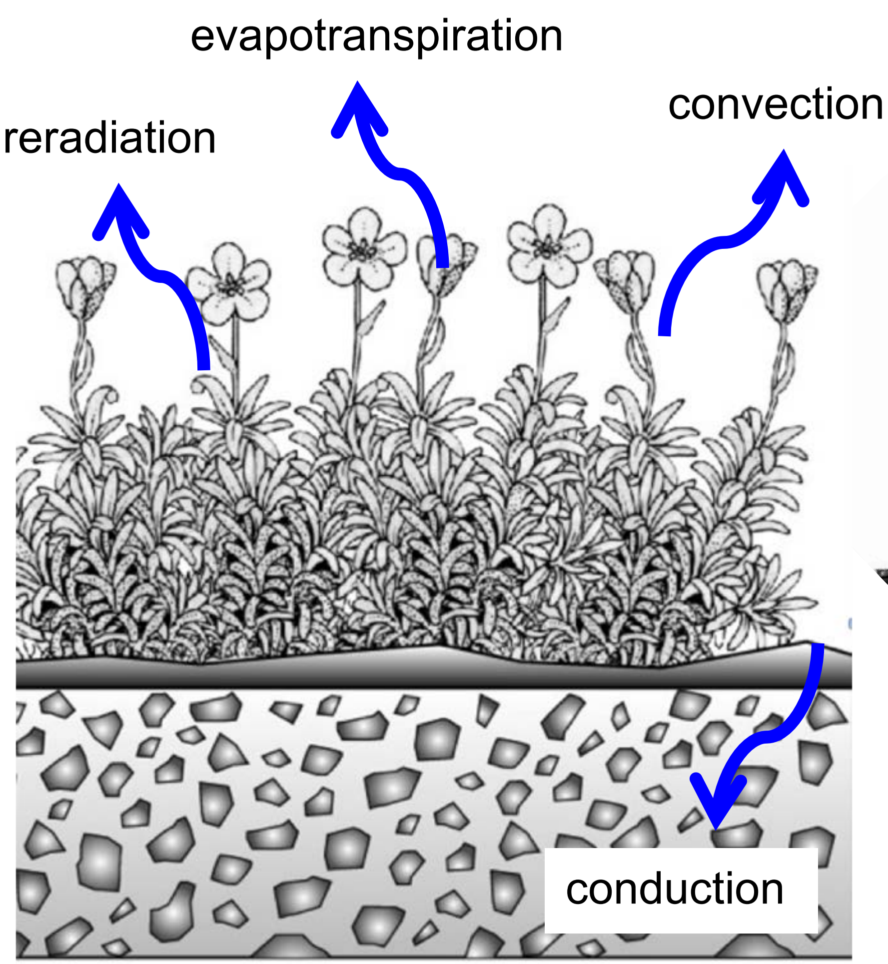
(part 2)

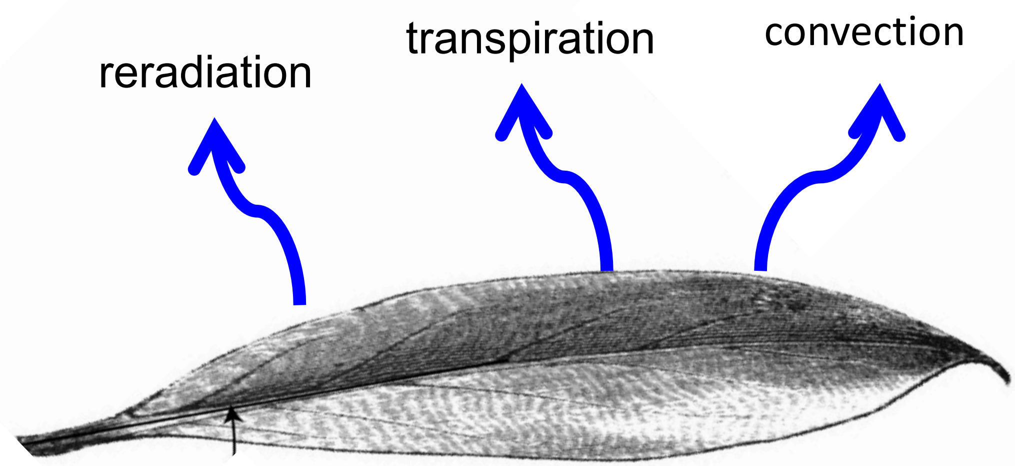
Plant Ecology in a Changing World

Jim Ehleringer, University of Utah
http://plantecology.net


Part 5
Radiation balance
and energy dissipation

Incoming energy is absorbed by a surface (leaf, hillside, animal) and converted and dissipated as





Less than 3 % of the absorbed energy is used in photosynthesis

Radiation balance of a ground surface (as an example)

Inputs

$$R_n = (1 - a)S_s + R_{IR\text{-}sky} - R_{IR\text{-}ground}$$

net radiation

albedo or reflectance

infrared radiation from sky and ground/object

units are W m^{-2}

Reflectances of different ecological surfaces in the 100 - 4,000 nm waveband

	reflectance (%)
ocean	5
dry sand	18
bare ground	10 - 20
pasture	25
forest	18
snow	81

Radiation balance

outputs

$$R_n = H + \lambda E + G$$

sensible heat loss

latent heat loss

heat conduction into ground

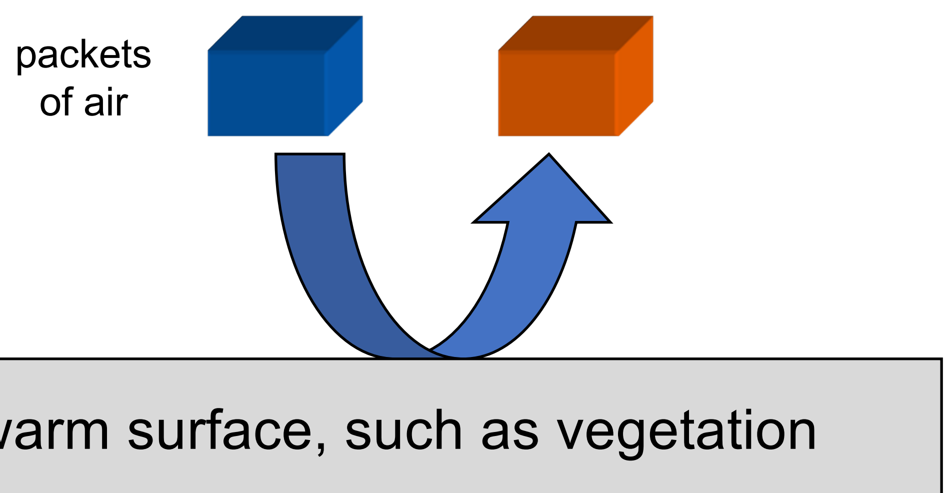
units for R_n are W m^{-2}

example is ground

Sensible heat loss

$$R_n = H + \lambda E + G$$

energy transferred from object to air by convection



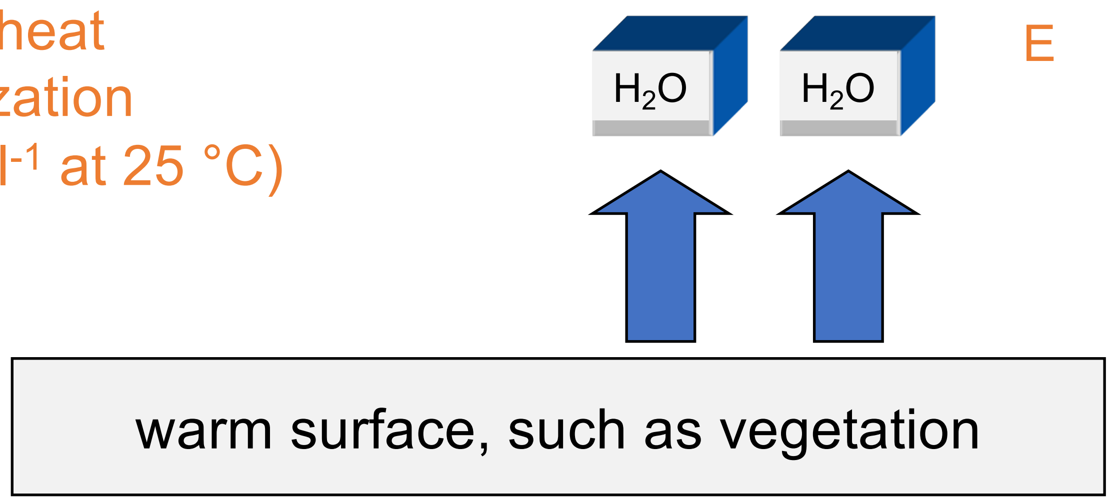
… warms air
during day

Latent heat loss

$$R_n = H + \lambda E + G$$

energy transferred from object to air by evaporation

λ is the heat of vaporization (4.4×10^4 J mol^{-1} at 25 °C)



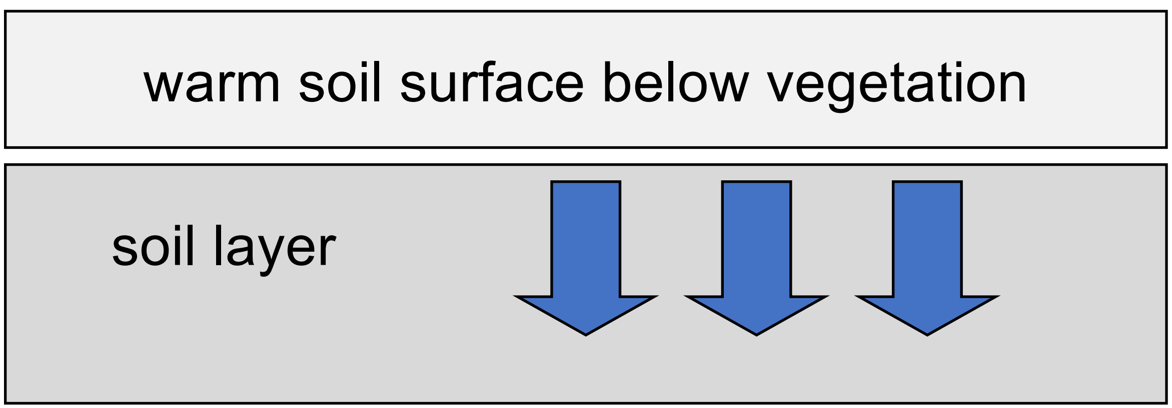
E

… humidifies the air

Conductive heat loss

$$R_n = H + \lambda E + G$$

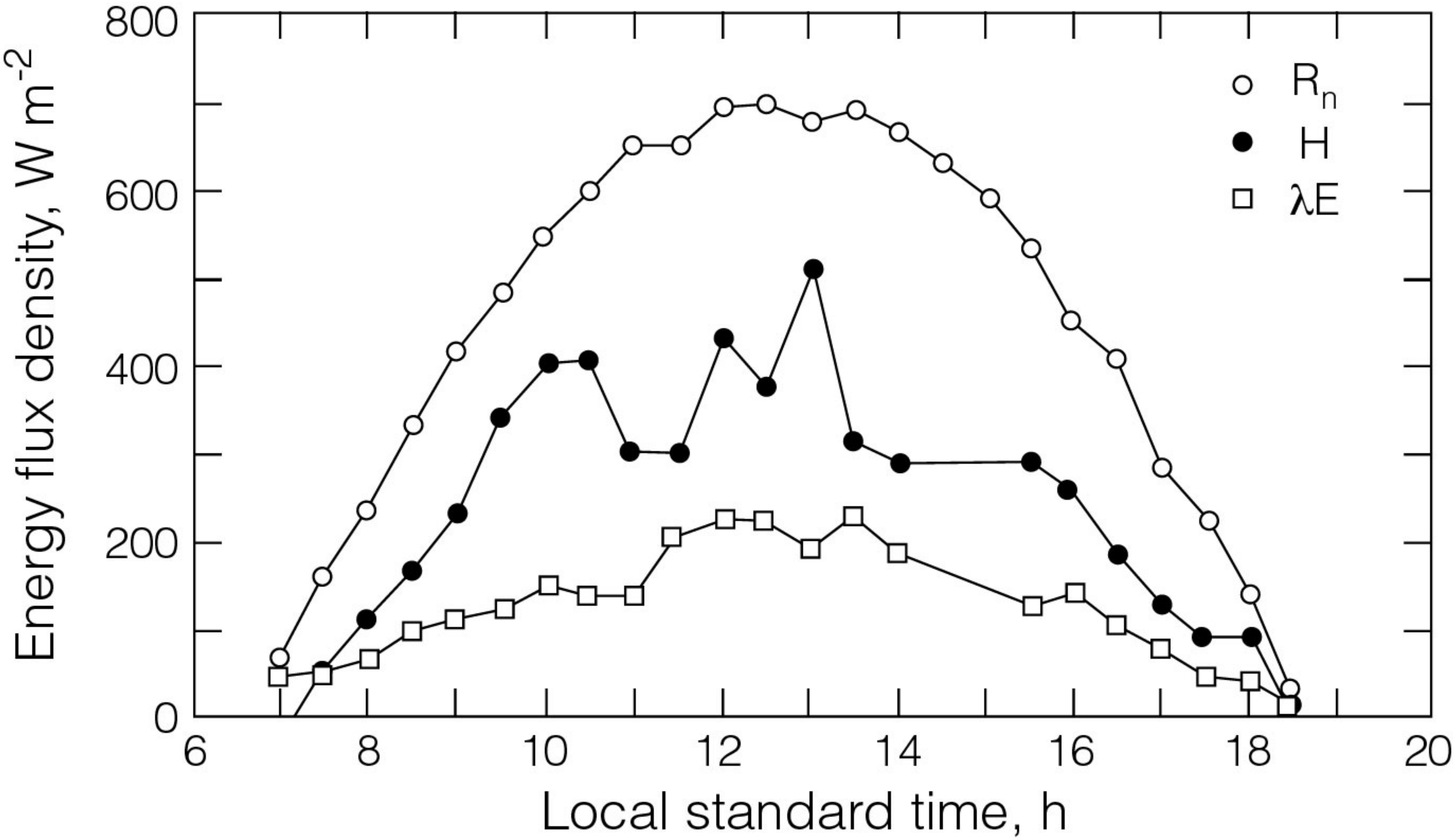
energy transferred from object to soil by conduction



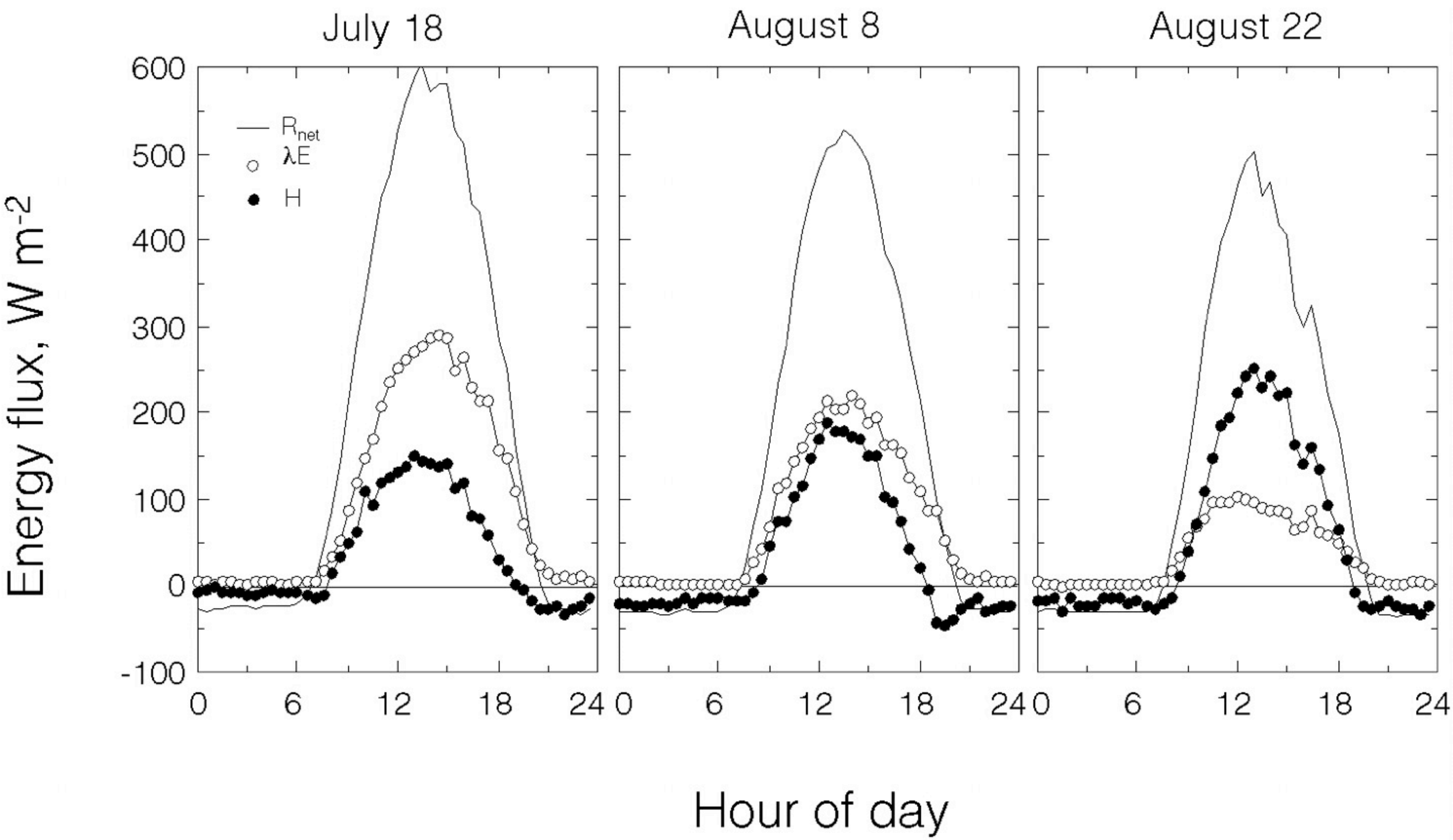
G

… warms soil during day

We can see the diurnal net radiation patterns in a deciduous forest, where sensible heat loss often exceeds evaporative energy loss



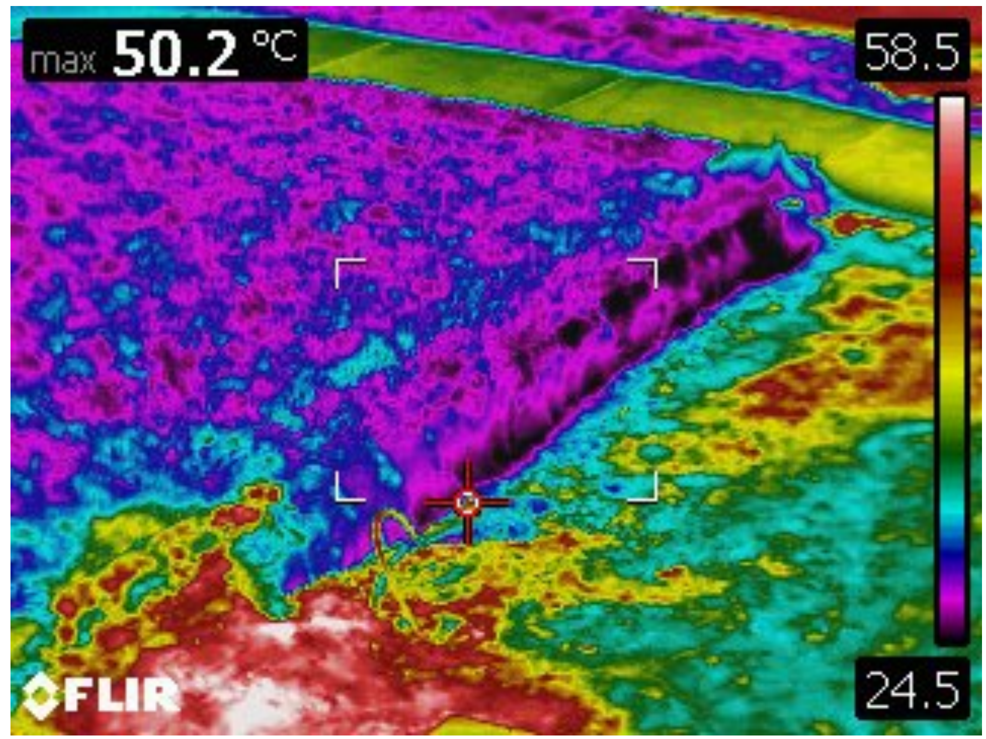
In contrast, the energy dissipation patterns change over the season within a grassland as the soil moisture level draws down



Spatial patterns can be seen on a local scale

Visualizing spatial patterns as distinct microclimates:

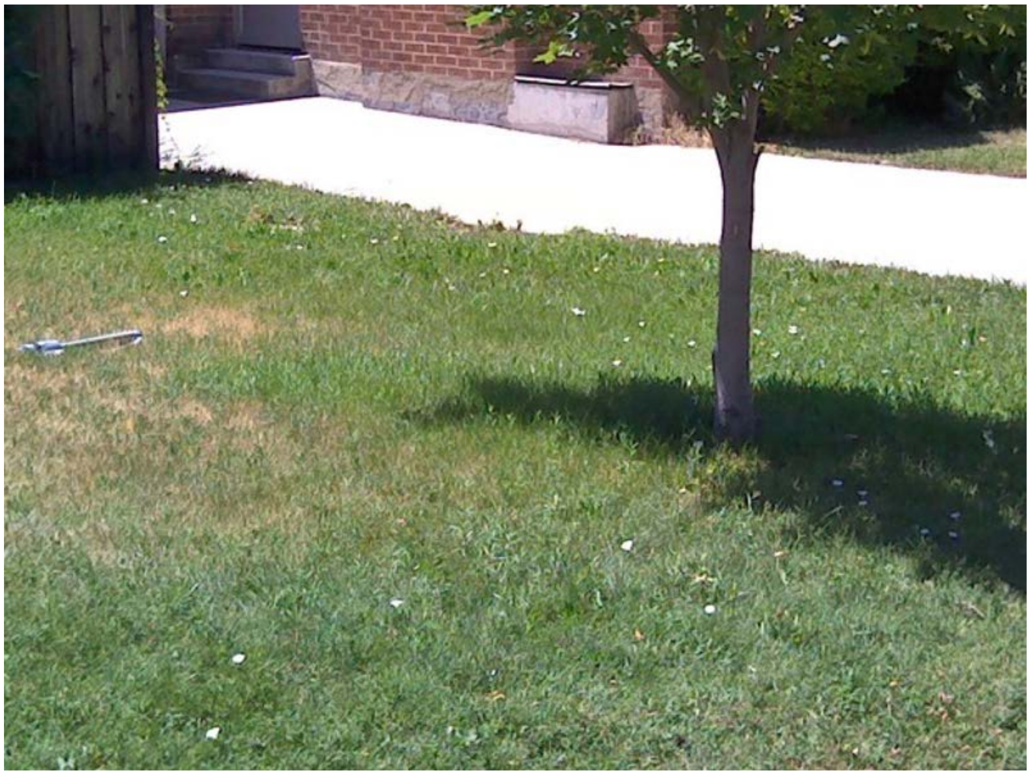
a 25°C range across lawn and bare soil in this front yard

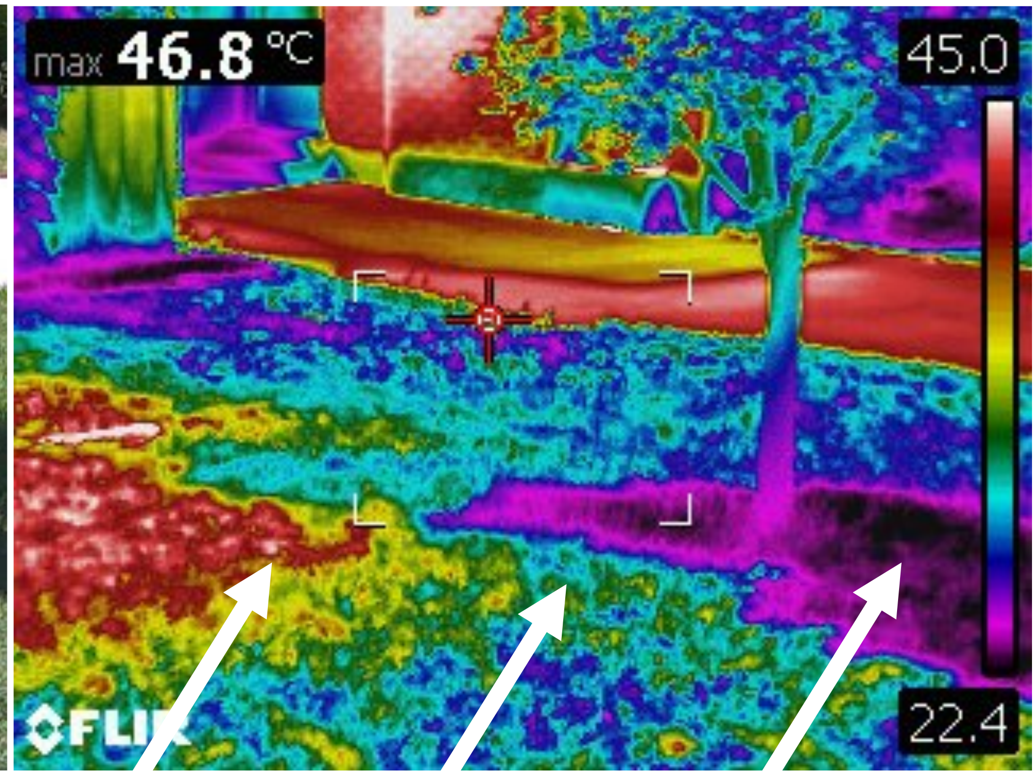


Note that the non-transpiring edge of the lawn is at a temperature similar to bare soil

Visualizing spatial patterns as distinct microclimates:

a 25°C range across sun and shade portions of a lawn



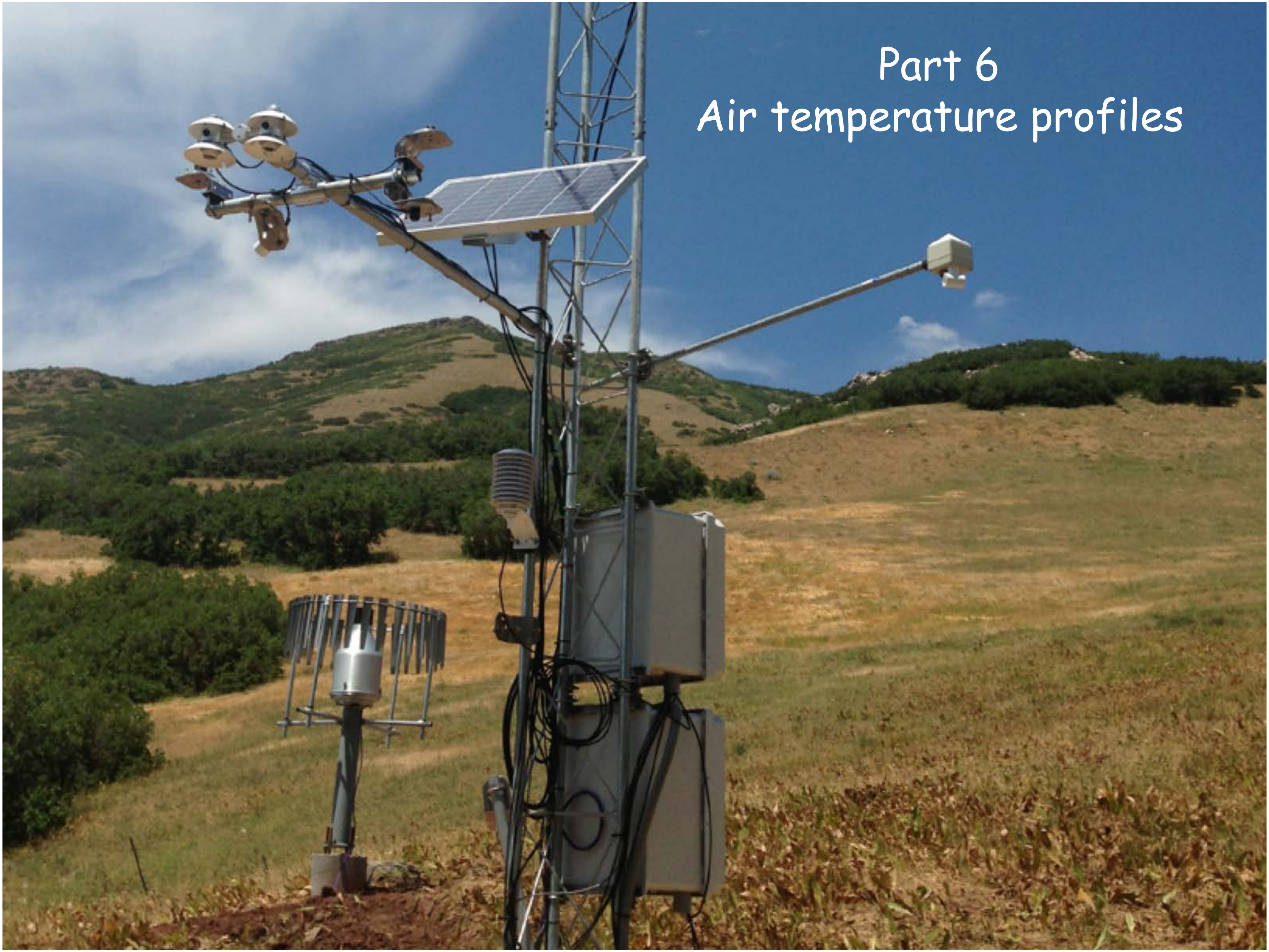


unwatered bindweed

sun grass

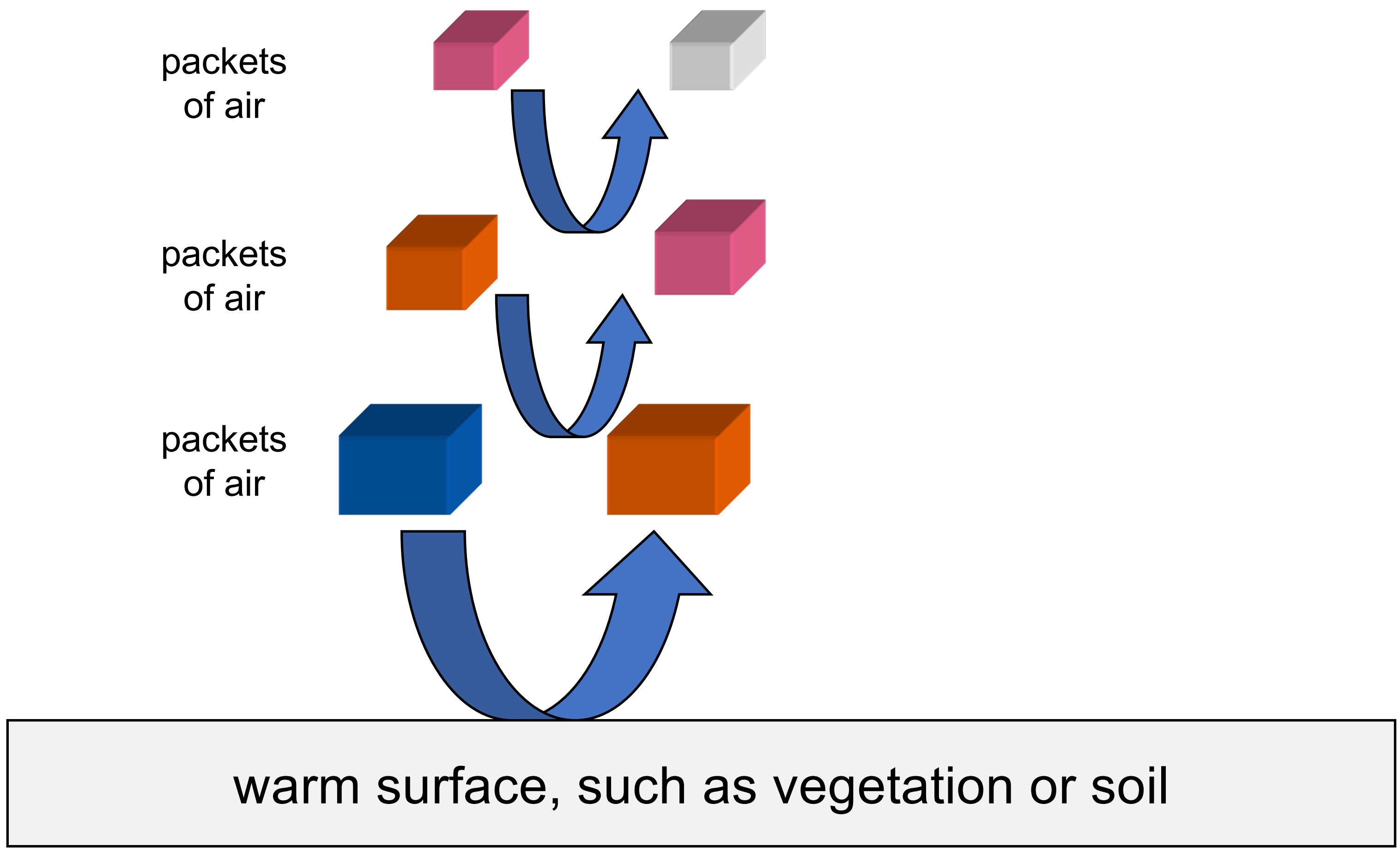
shade grass

Note that the left portions of the lawn are occupied by bindweed and are transpiring less; hence the presence of the water sprinkler

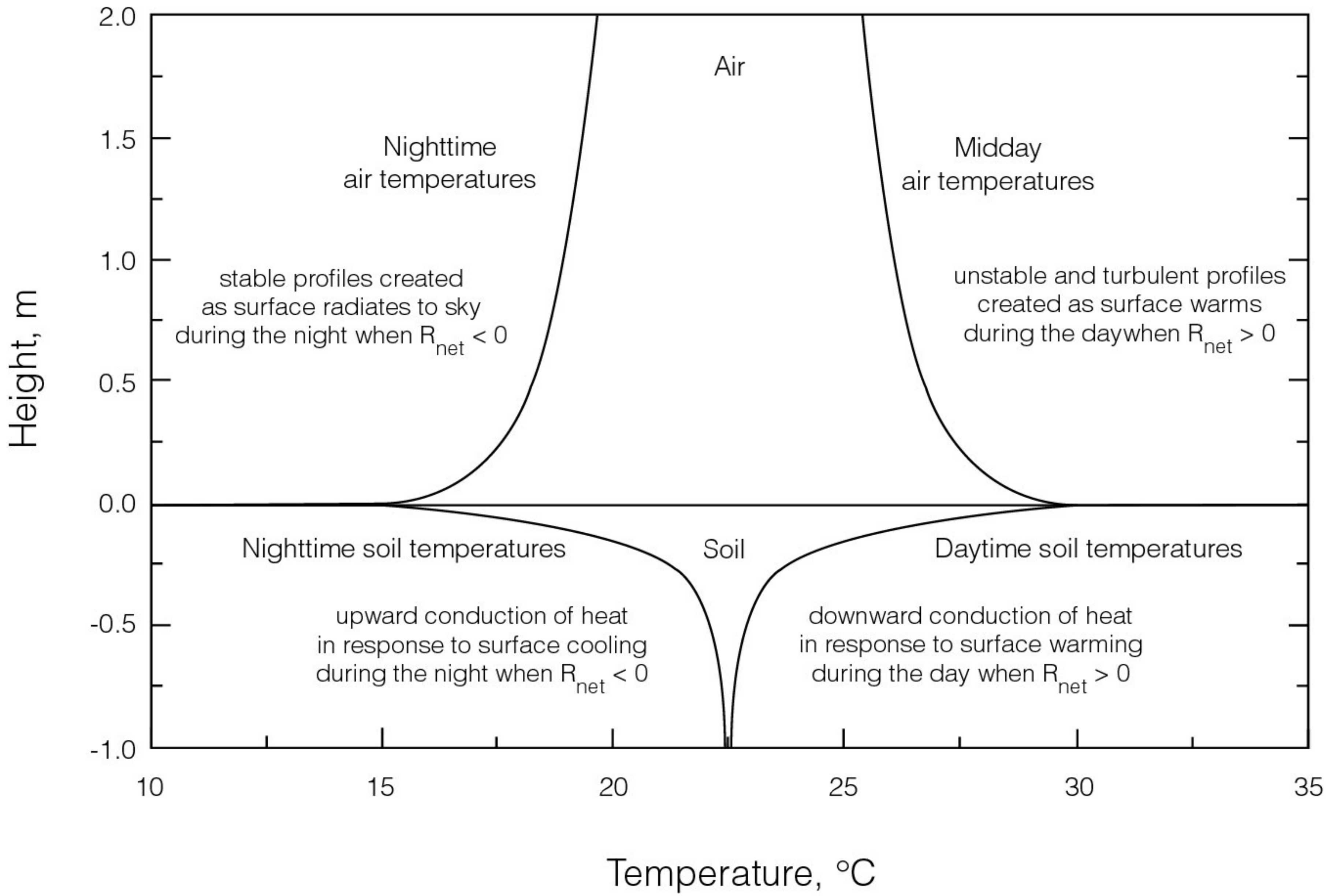

Part 6
Air temperature profiles

The manner by which net radiation is dissipated determines the magnitude of diurnal temperature warming

Air temperature profiles develop by energy exchange with the surface, not by solar energy absorption by atmospheric gases

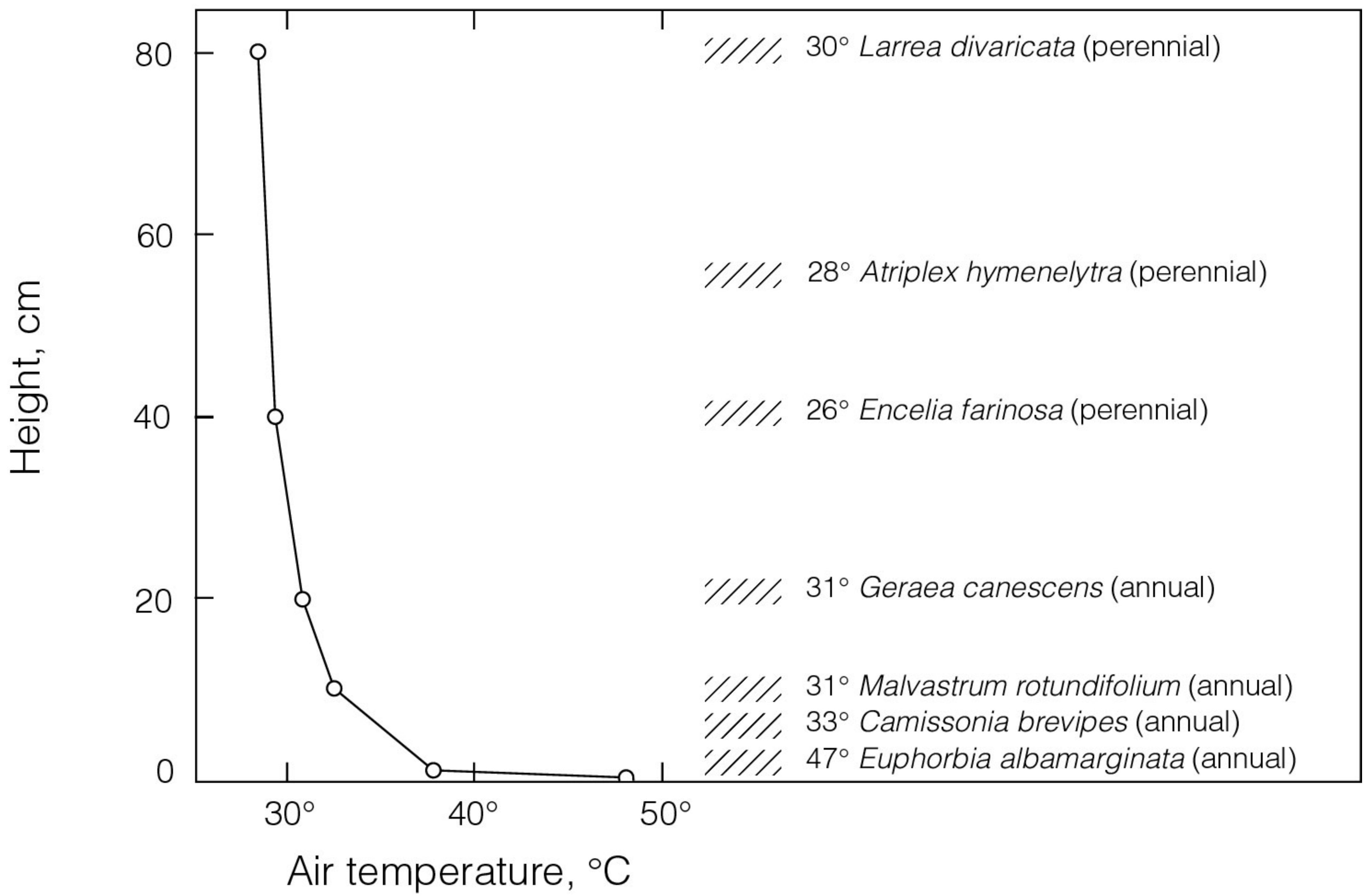


General patterns of microclimatic profiles over bare ground

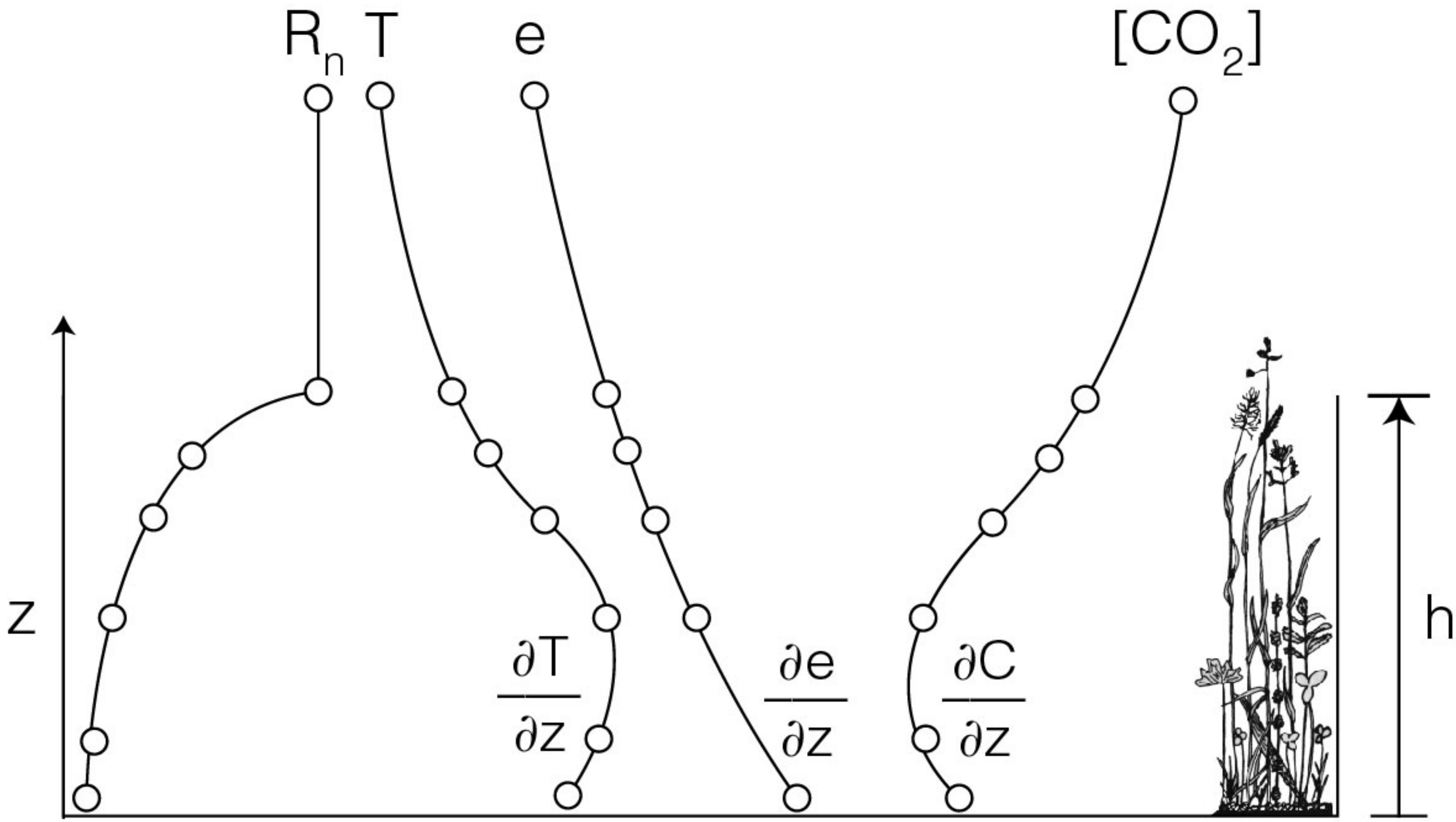



Mojave Desert plants

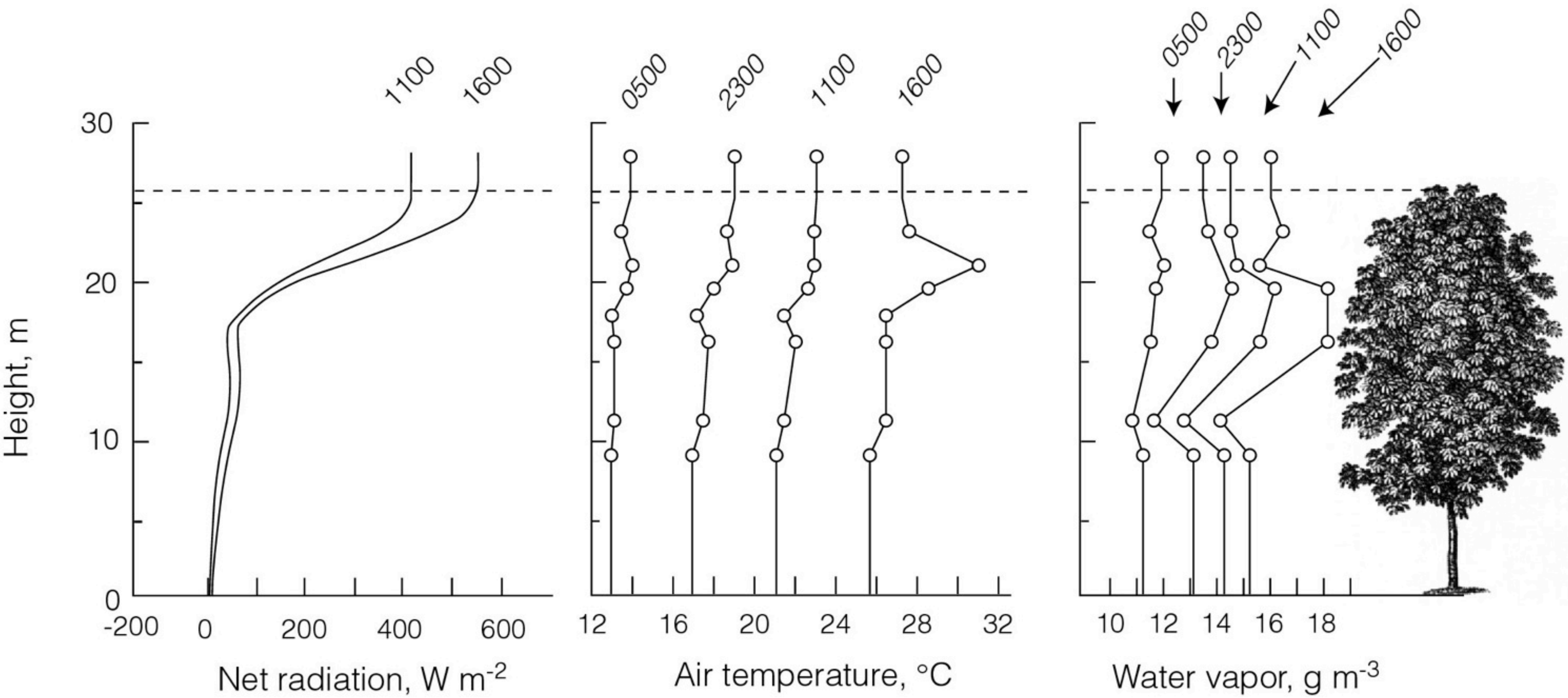
Springtime air and leaf temperature profiles in deserts

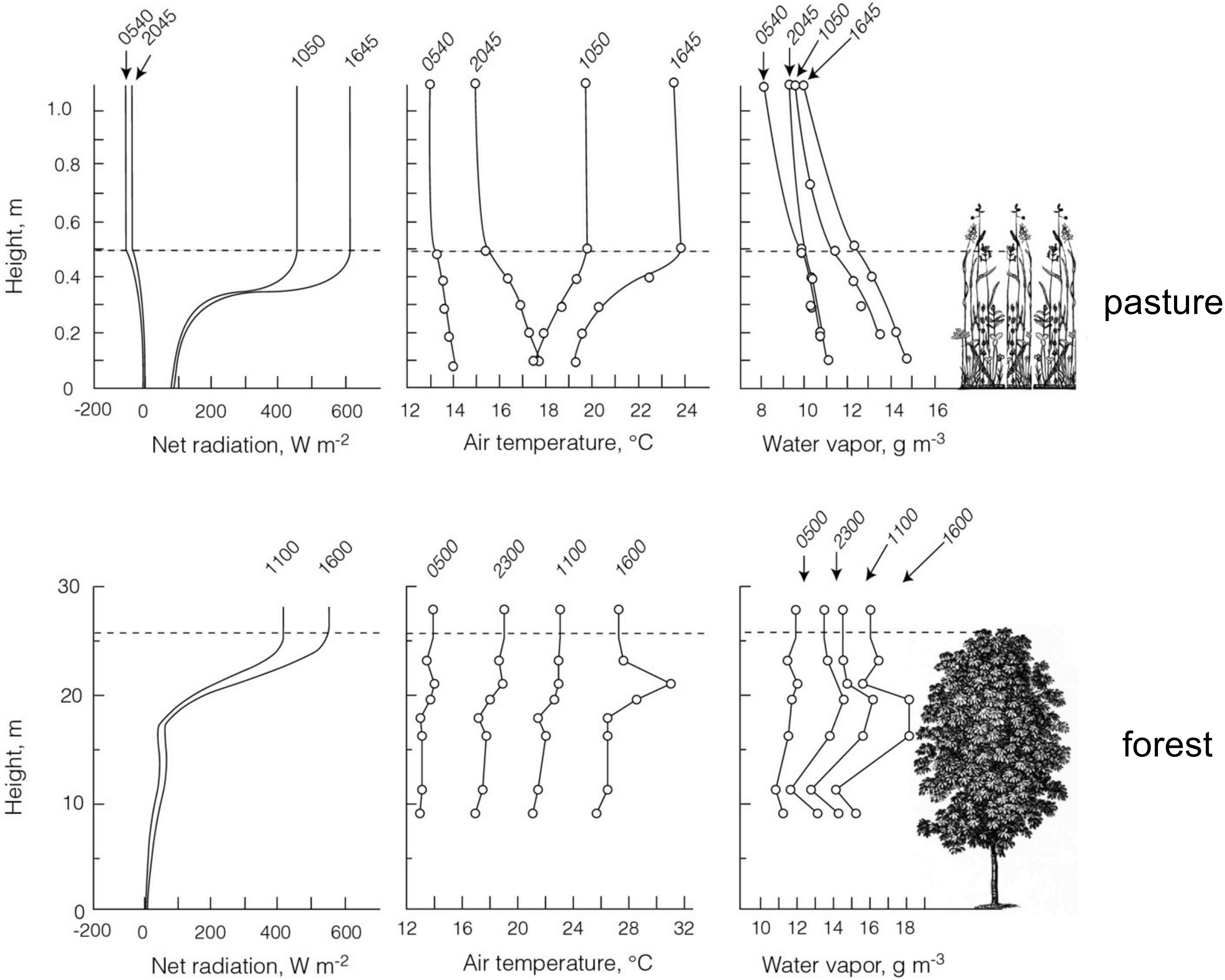


The presence of vegetation alters energy absorption patterns and creates “bulge” air temperature profiles



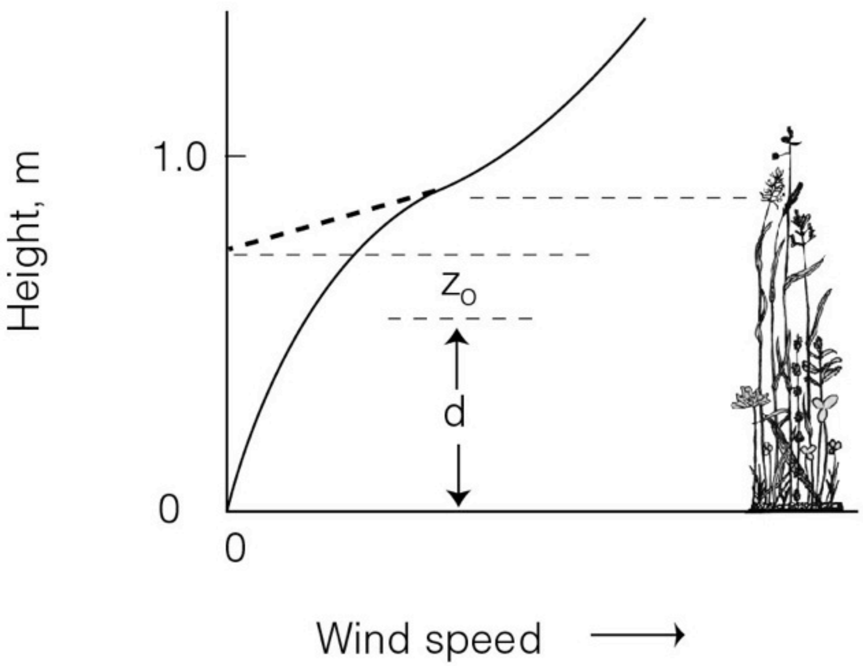
Microclimate profiles with a deciduous forest

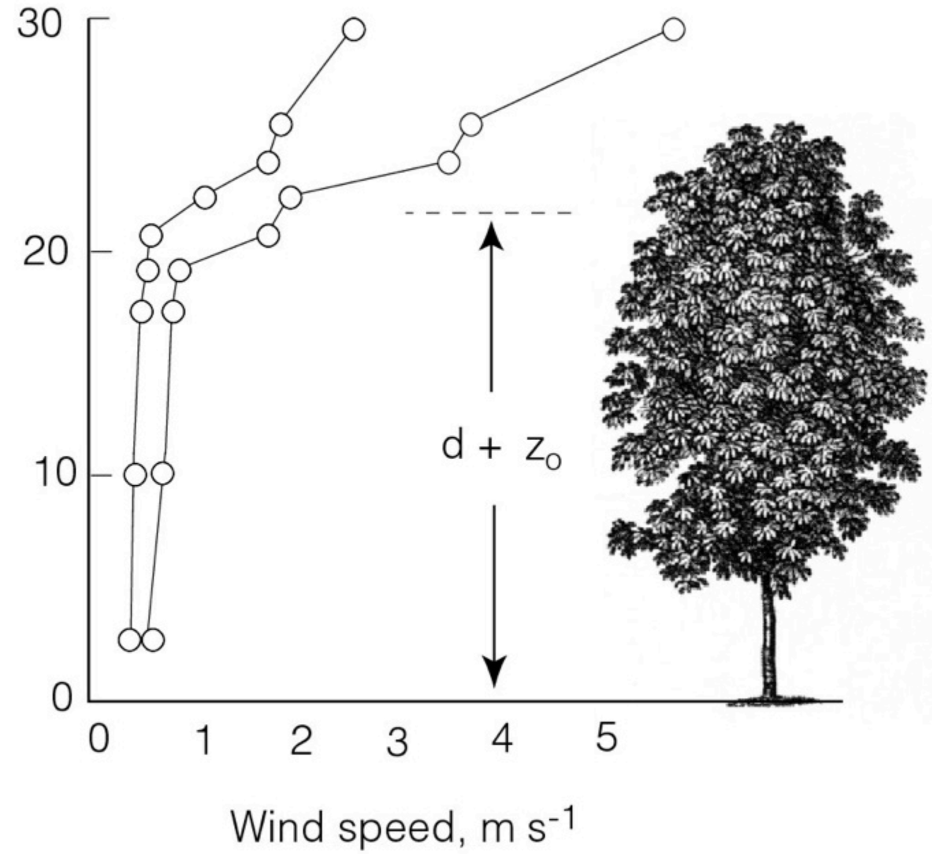




0540
2045
1050
1645
Height, m
Net radiation, W m-2
Air temperature, °C
Water vapor, g m-3
pasture
0500
2300
1100
1600
forest

Wind speed decreases exponentially above the vegetation

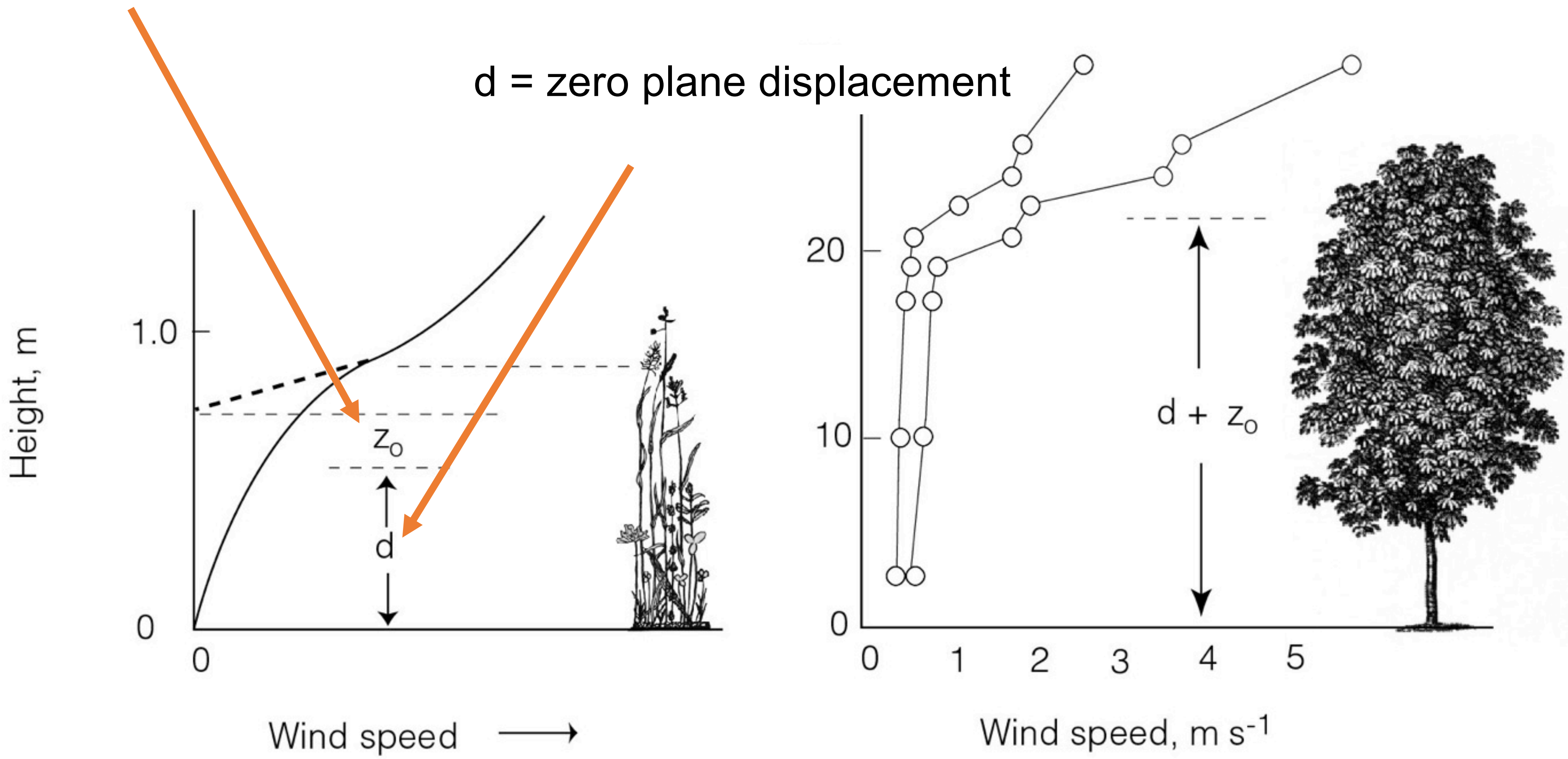




$z_o + d$ = height at which expected exponential decay would have resulted in a wind speed of 0

z_o = roughness parameter

d = zero plane displacement

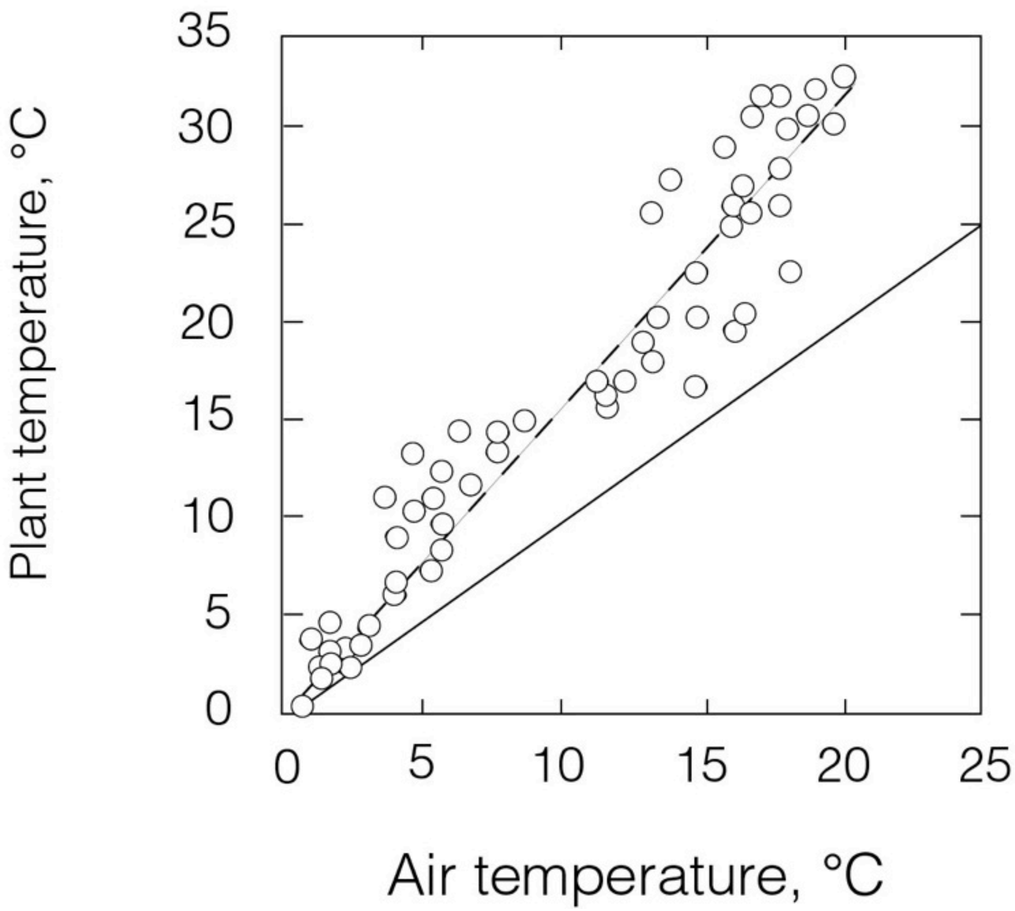


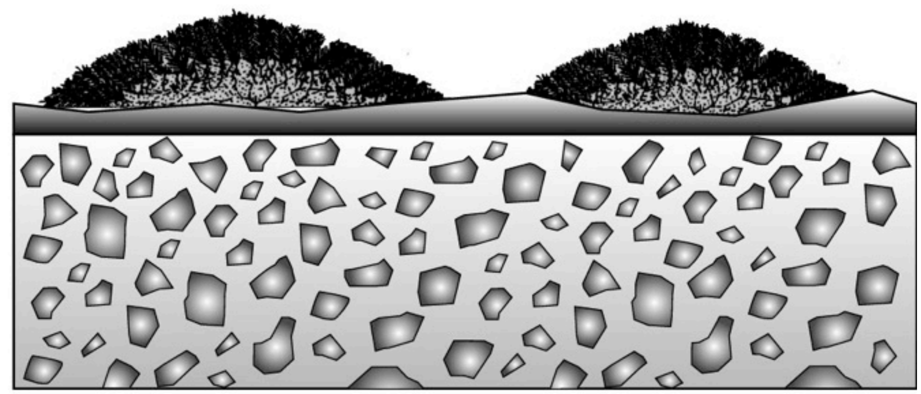
d = position in canopy where half of the momentum is absorbed

Cold - the other temperature extreme

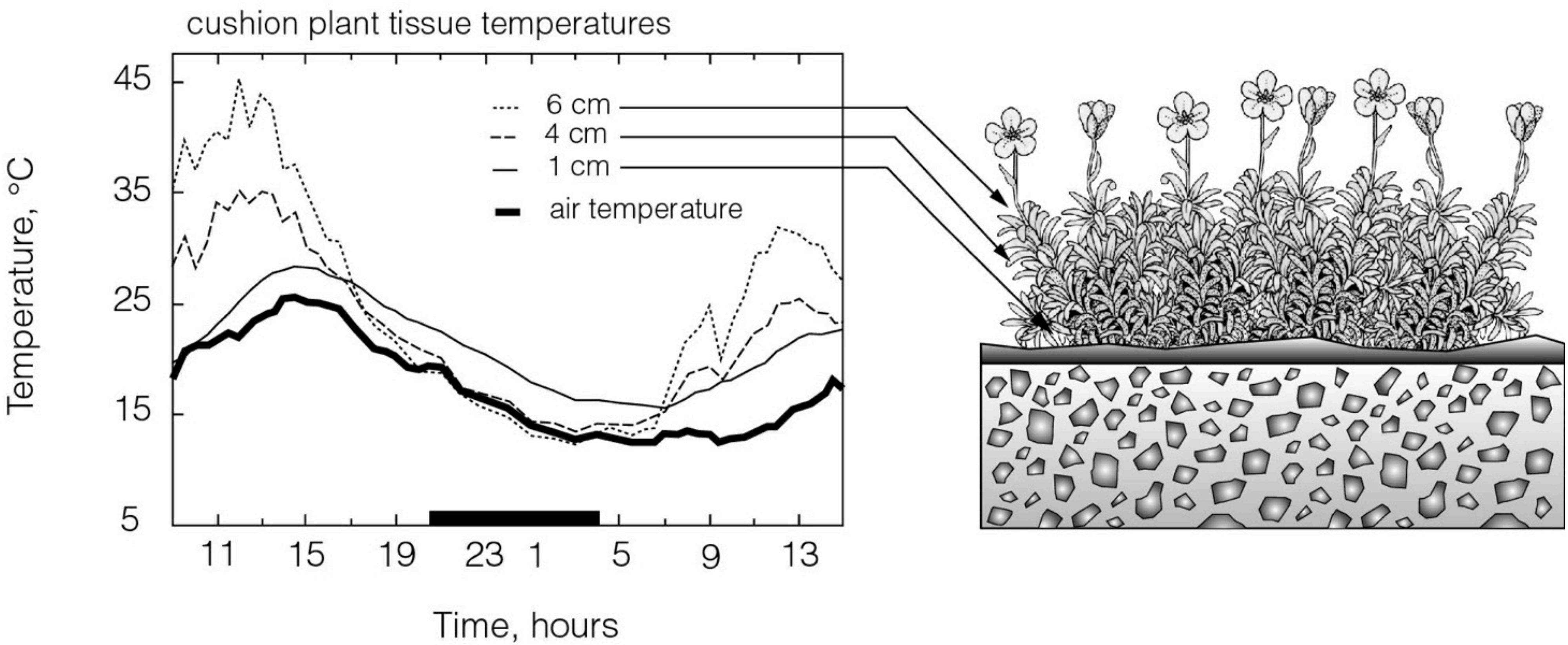
… cushion plants (*Silene* sp.) in the alpine tundra

Tightly-packed plants in the alpine tundra experience reduced wind speeds, and given low transpiration rates, experience elevated temperatures

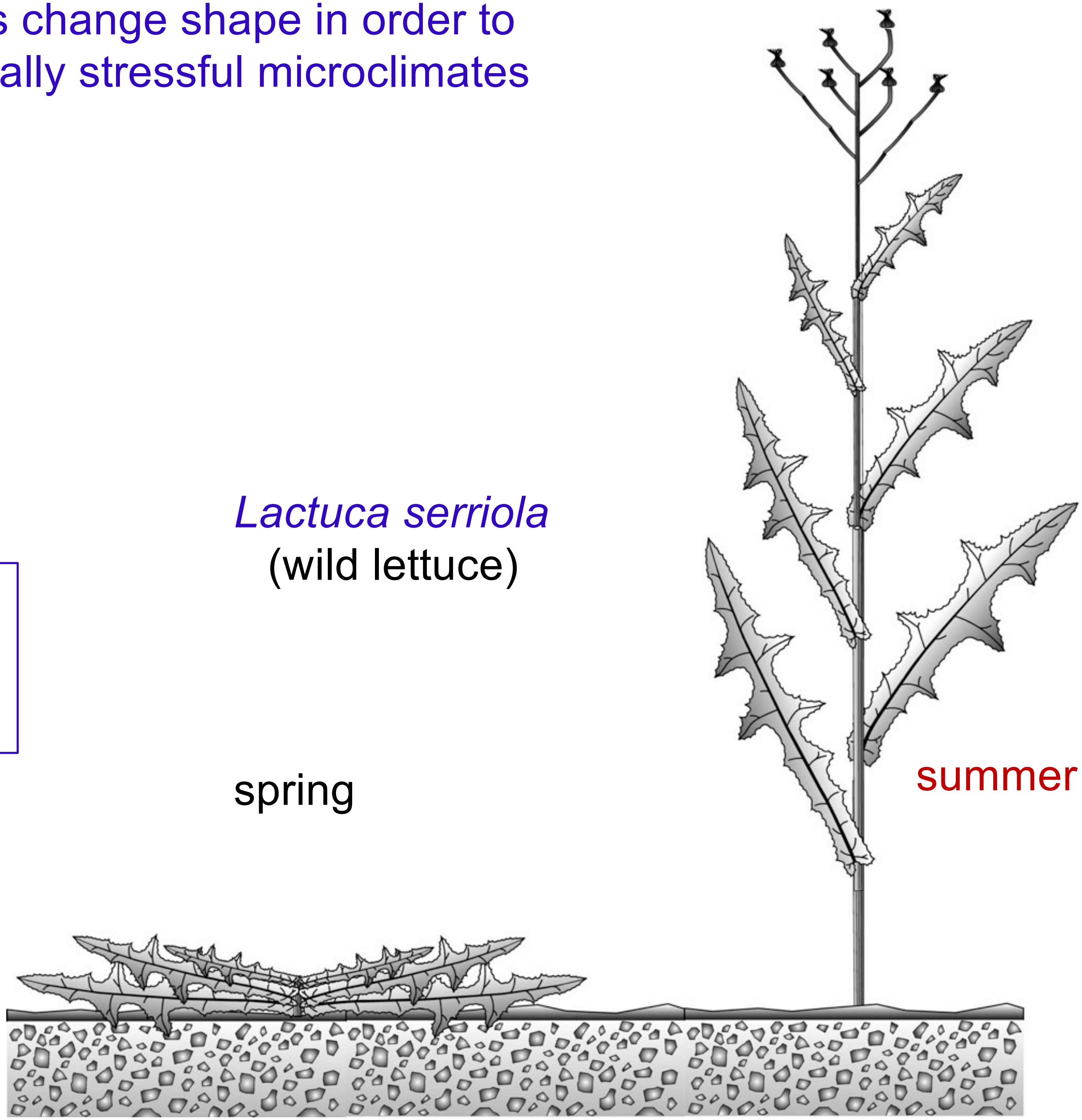




Tightly-packed plants in the alpine tundra experience reduced wind speeds and have elevated temperatures



Some plants change shape in order to avoid potentially stressful microclimates

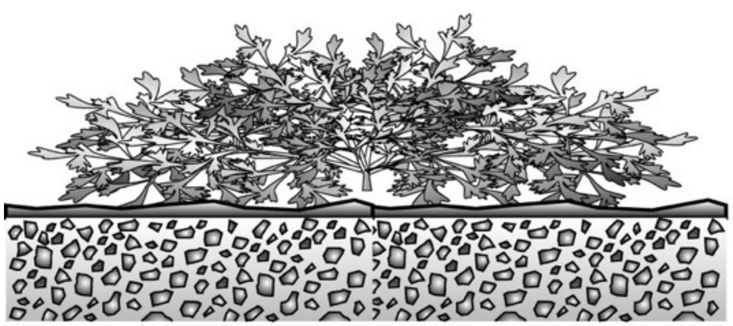


The physiognomical change is the result of simple extensions in internodal distances

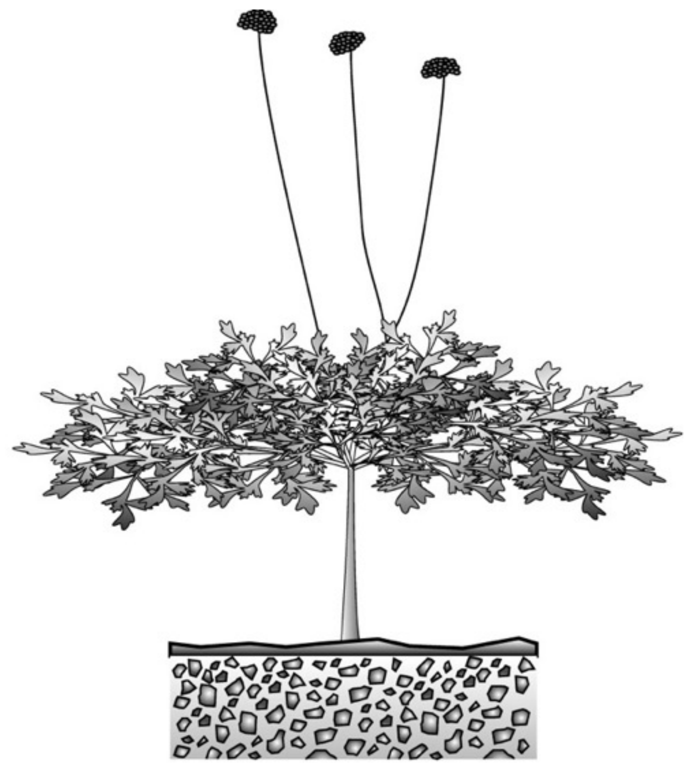
Some plants change height in order to avoid potentially stressful microclimates

Here the physiognomical change is the result of an extension of the basal portion of the stem

Cymopterus longipes
long stalk springparsley

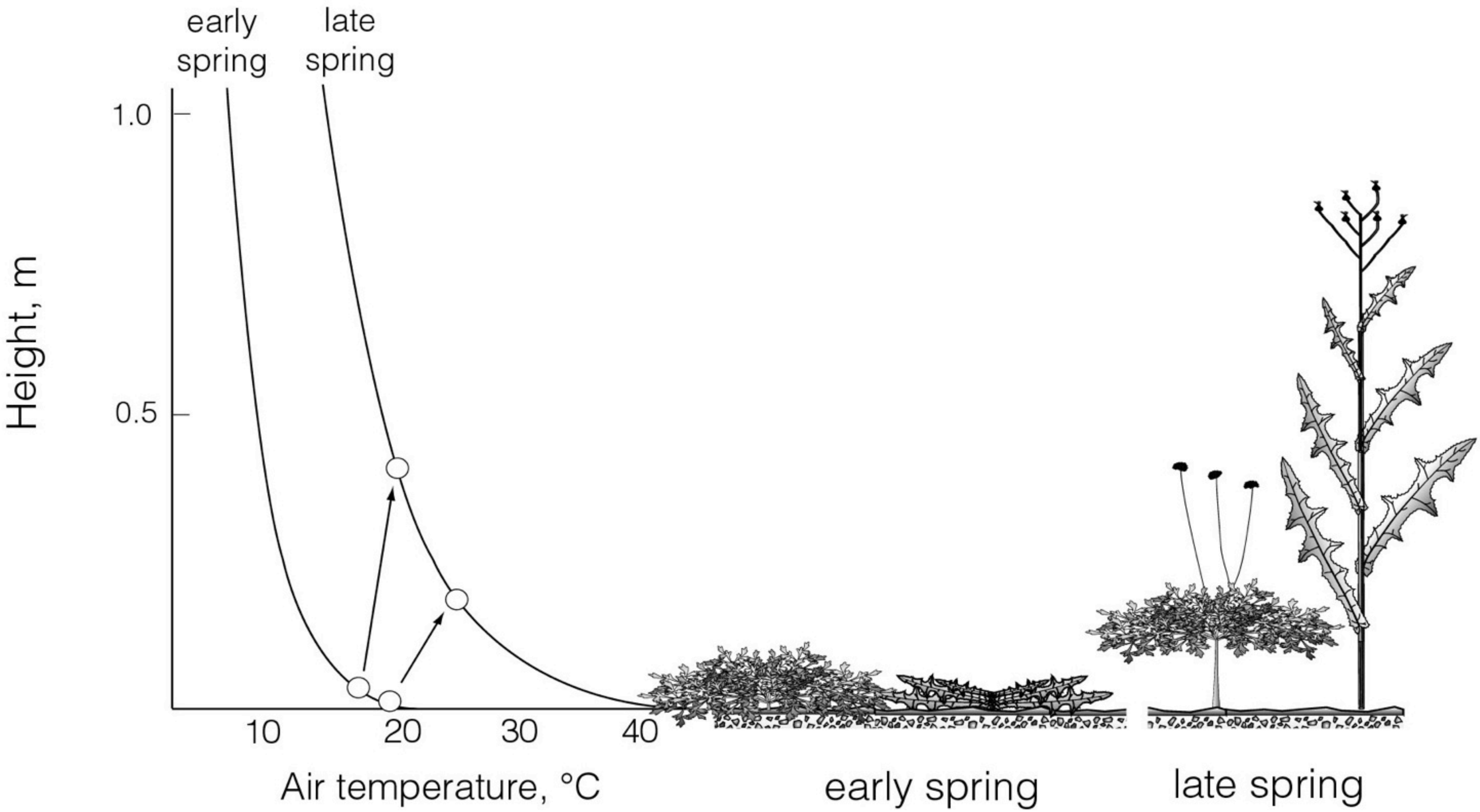


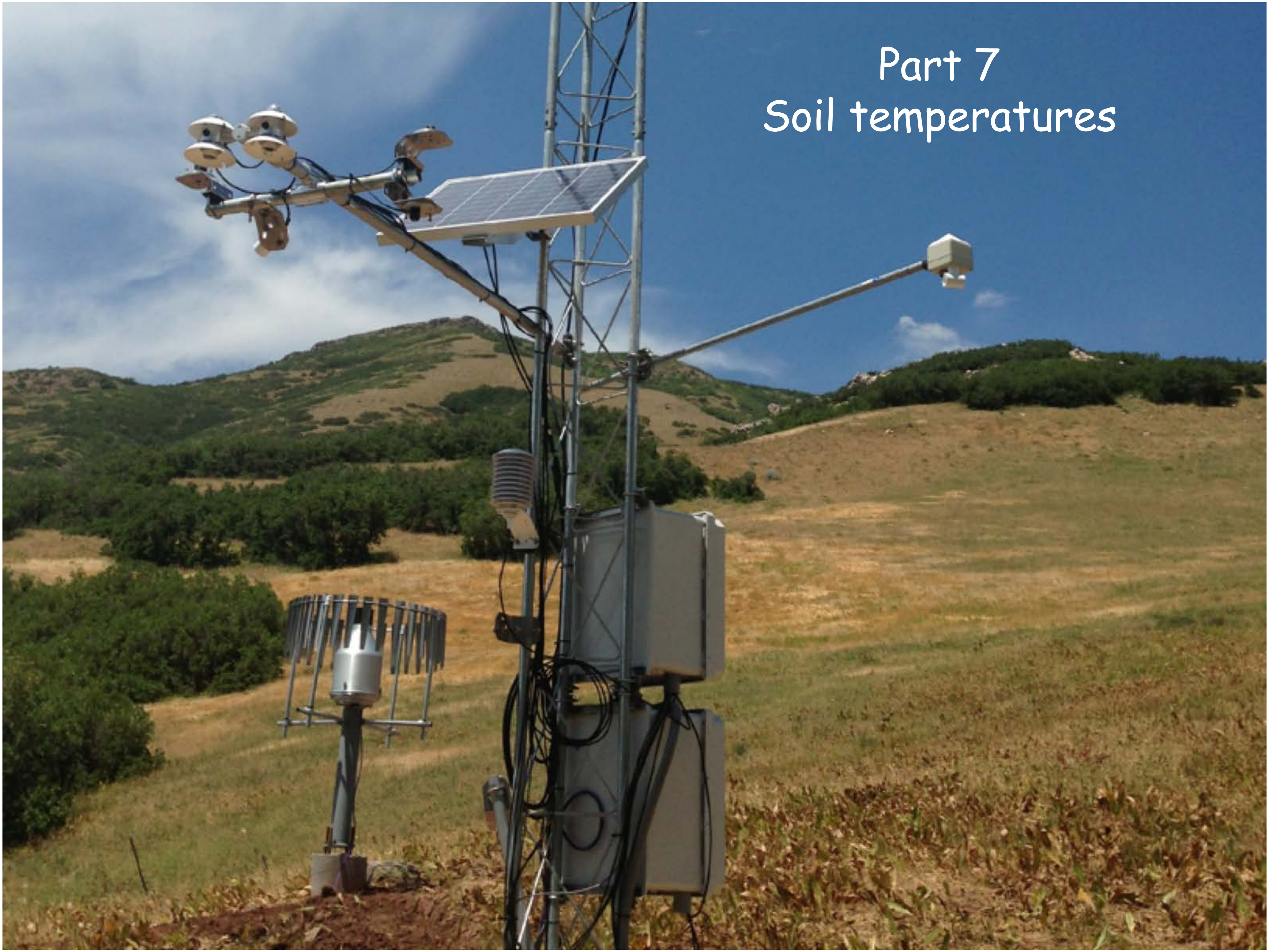
early spring



late spring

Their vegetative structures are elevated out of the warmest and driest part of the air temperature profile




Part 7
Soil temperatures

Soil temperatures fluctuations decrease with depth

$$T_{s\text{-}z} = \underbrace{(T_{s\text{-}max} + T_{s\text{-}min})/2}_{\text{average daily soil temperature at the surface}} + (T_{s\text{-}max} - T_{s\text{-}min})(e^{-z/D})\sin\underbrace{(\omega t - z/D)}_{\text{exponential decay and hourly lag that occurs with depth}}$$

average daily
soil temperature
at the surface

exponential decay
and hourly lag that
occurs with depth

D is damping depth

soil temperature
at depth z

Soil damping depth

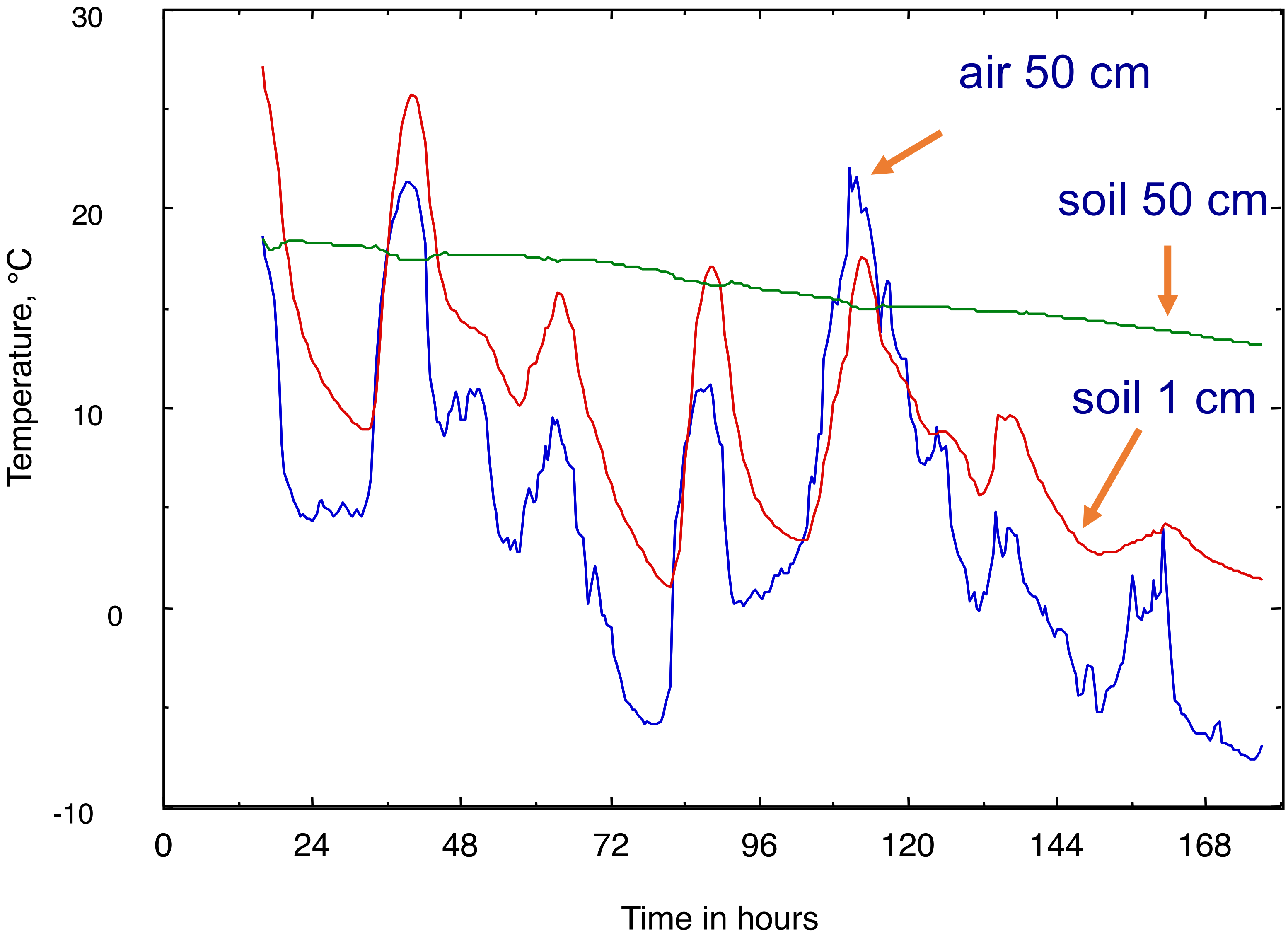
depth in soil required to see a 1/e reduction in daily amplitude

$1/e^3$ would be a 5 % fluctuation relative to soil surface

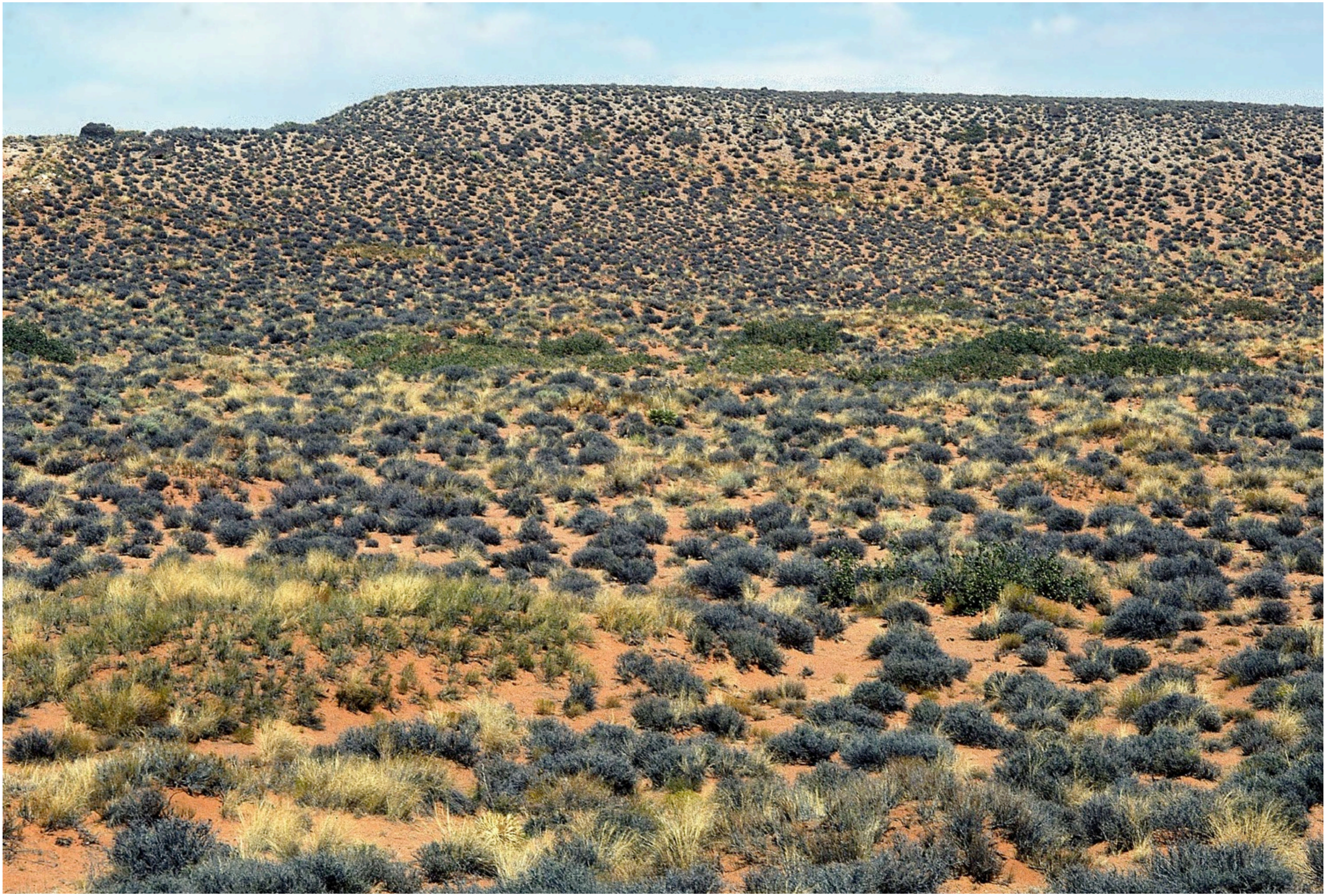
$$D = 0.06 \text{ m} \quad \text{dry soil}$$
$$= 0.15 \text{ m} \quad \text{wet soil}$$

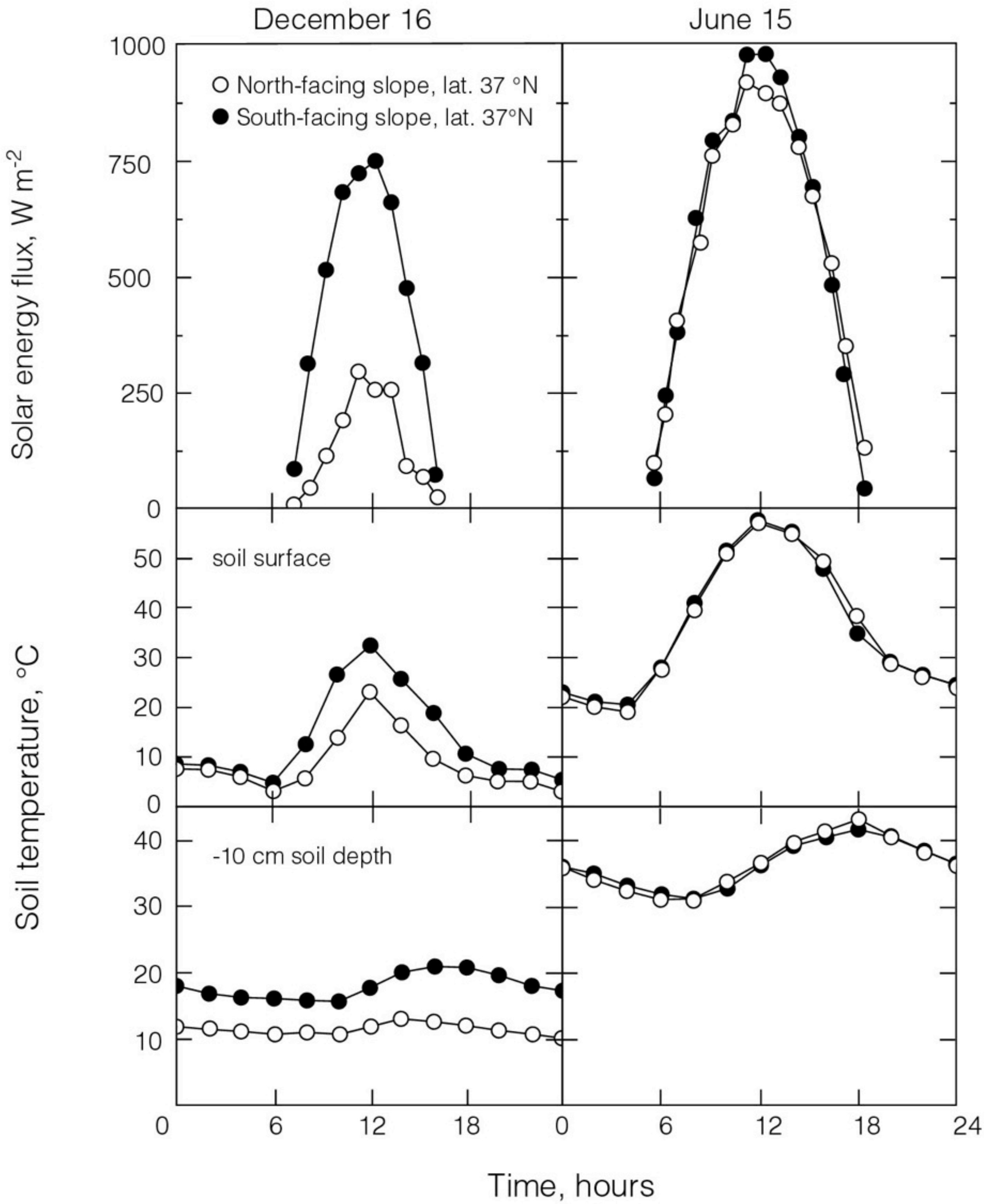
D on an annual basis is ~ 19x higher than on a daily basis

Class observations of air and soil temperatures with depth in the foothills behind campus. Data were collected in BIOL 5465 during October



Life at the microclimatic edge . . .





Sonoran Desert site

North- and south-facing slopes have different incident solar energy levels during the winter, resulting in reduced soil temperatures on north-facing slopes.

However, by summer, the sun is overhead, resulting in similar solar energy loads and similar soil temperatures on both slopes.

Arctic tundra soil temperatures

Soil temperatures in the arctic tundra of northern Siberia remain below 0°C throughout much of the year, rising above 0°C for only 1-4 months per year depending on soil depth.

Temperature changes in the arctic are rising faster than in temperate and tropical zones, leading to melting of permafrost at greater depths over time.

Melting permafrost leads to greater soil CO_2 respiration and methane emissions as organic matter at depth is metabolized.