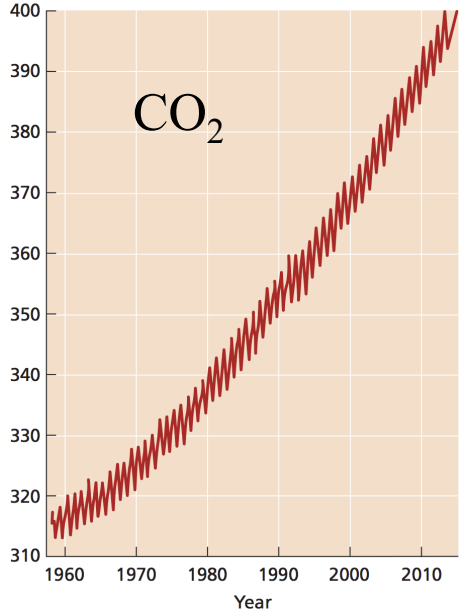
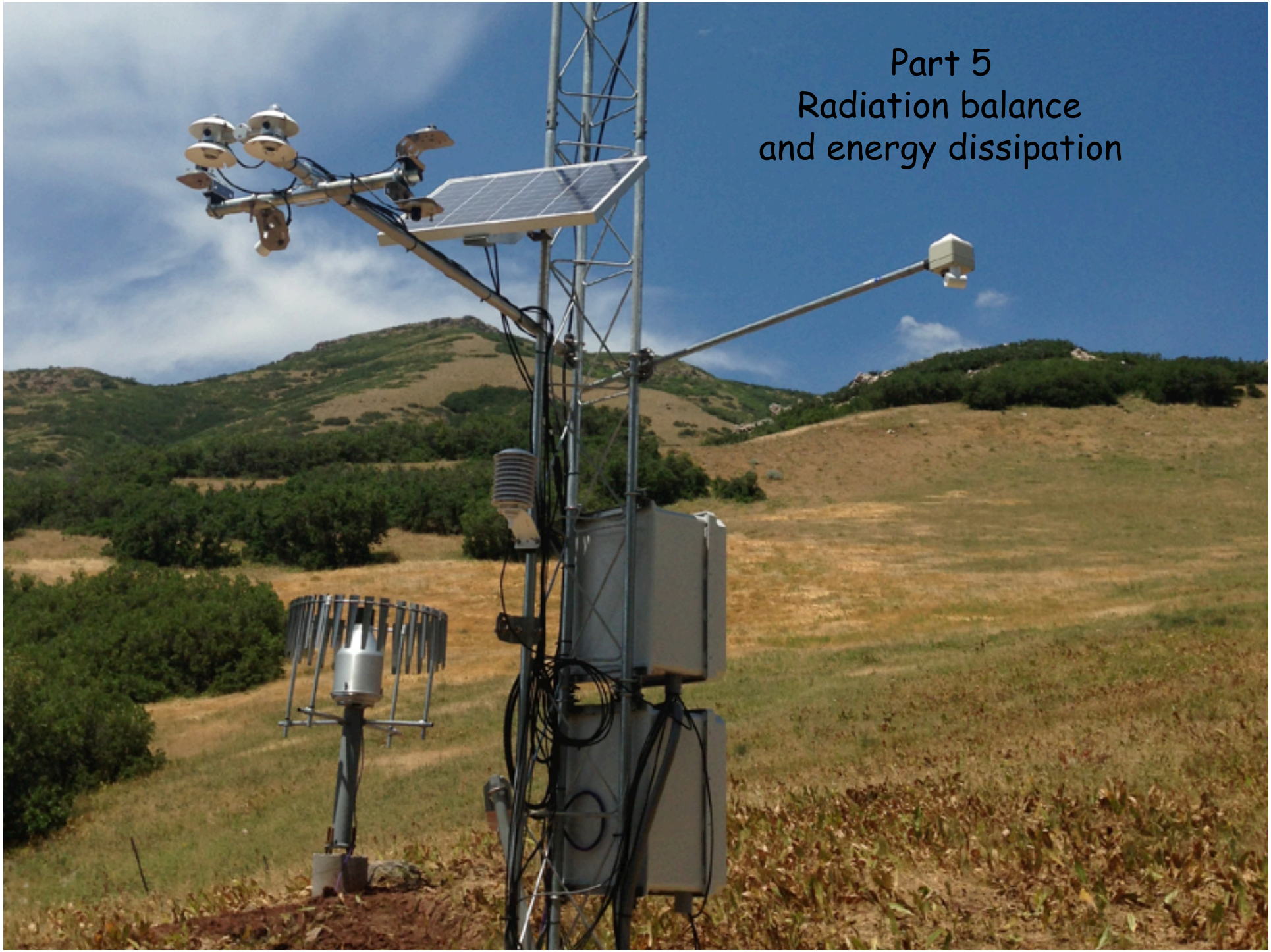


Macroclimates and microclimates

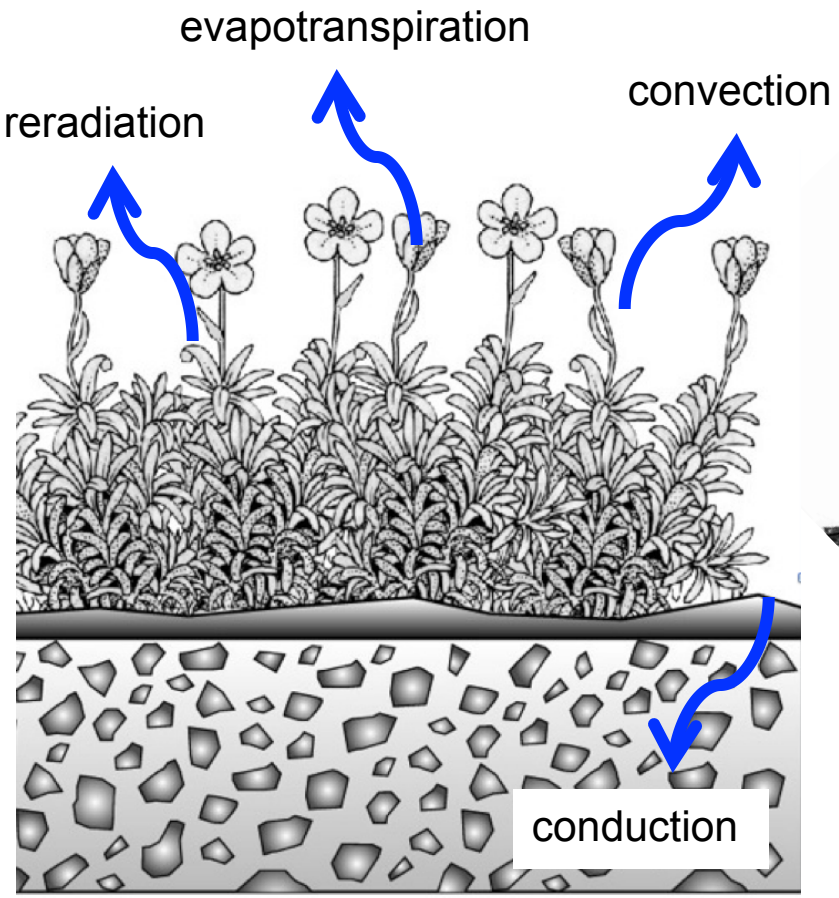
Plant Ecology in a Changing World

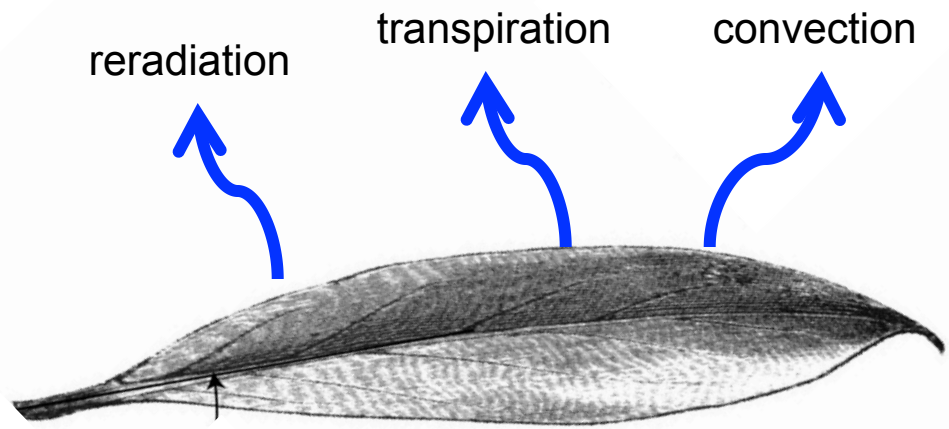
Jim Ehleringer, University of Utah
http://plantecology.net



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

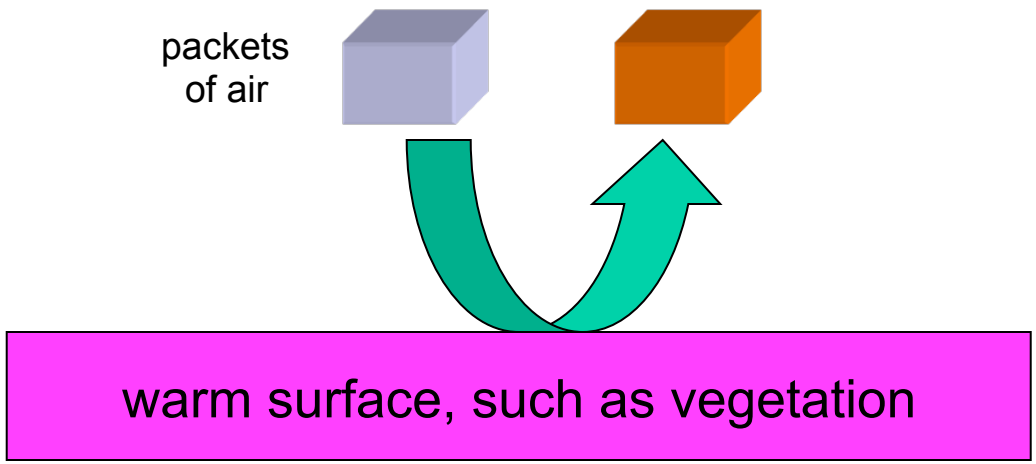
units for R_n are W m^{-2}

example is ground

Sensible heat loss

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

energy transferred from object to air by convection



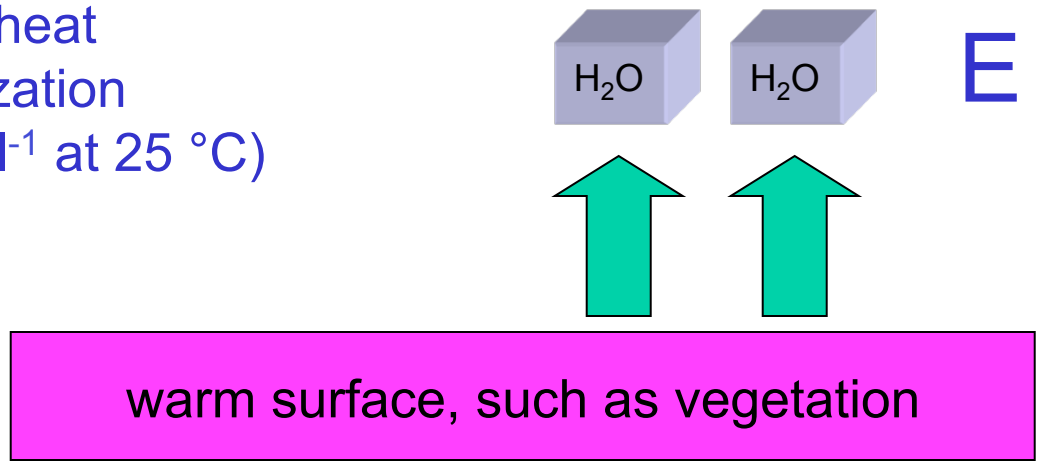
… warms air
during day

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)

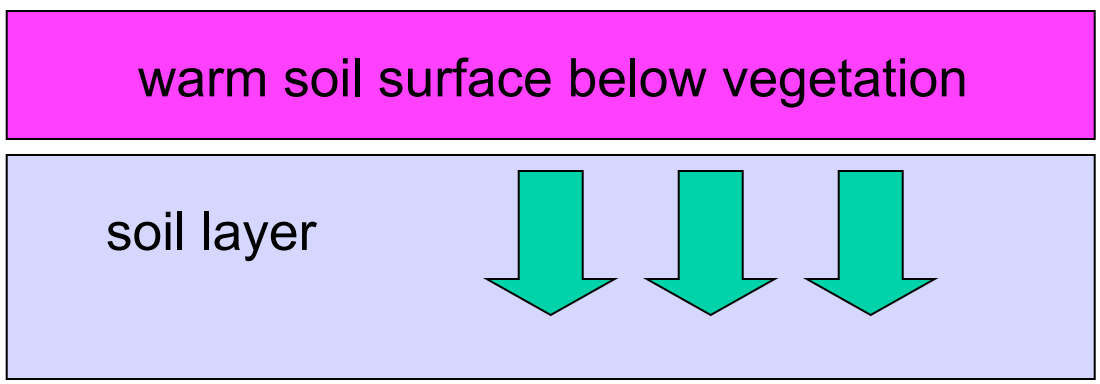


… humidifies
the air

Conductive heat loss

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

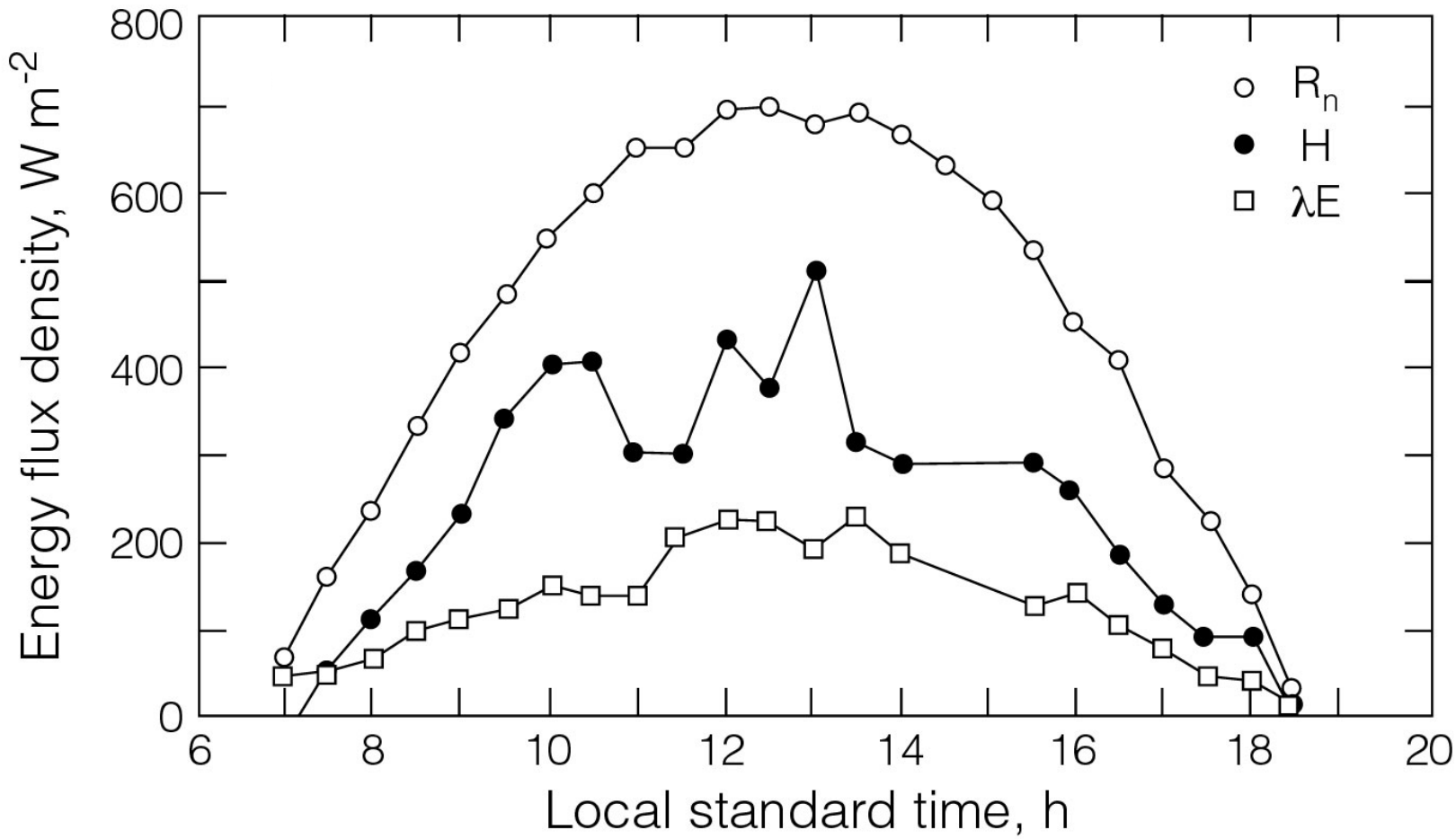
energy transferred from object to soil by conduction



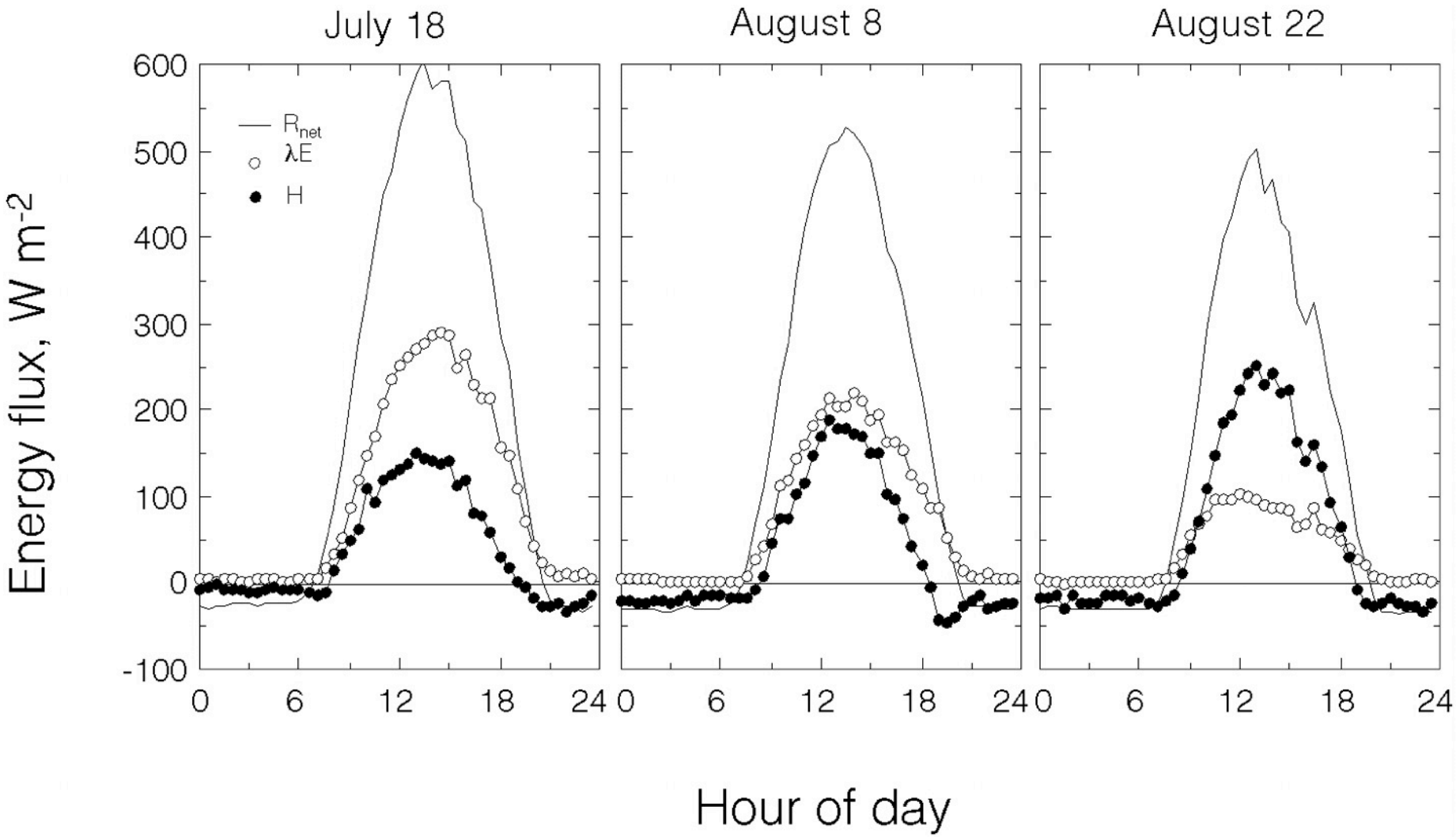
G

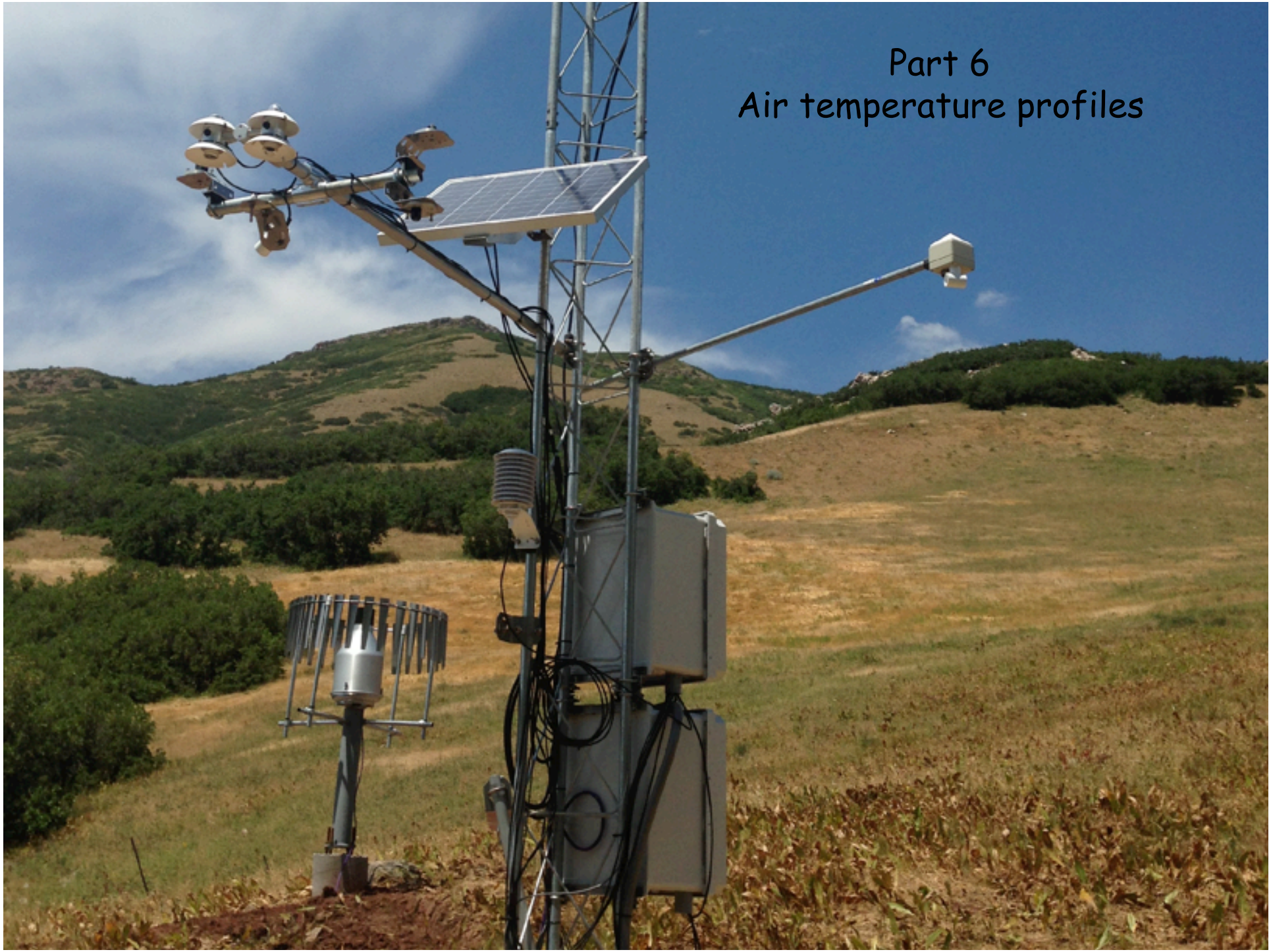
… warms soil during day

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



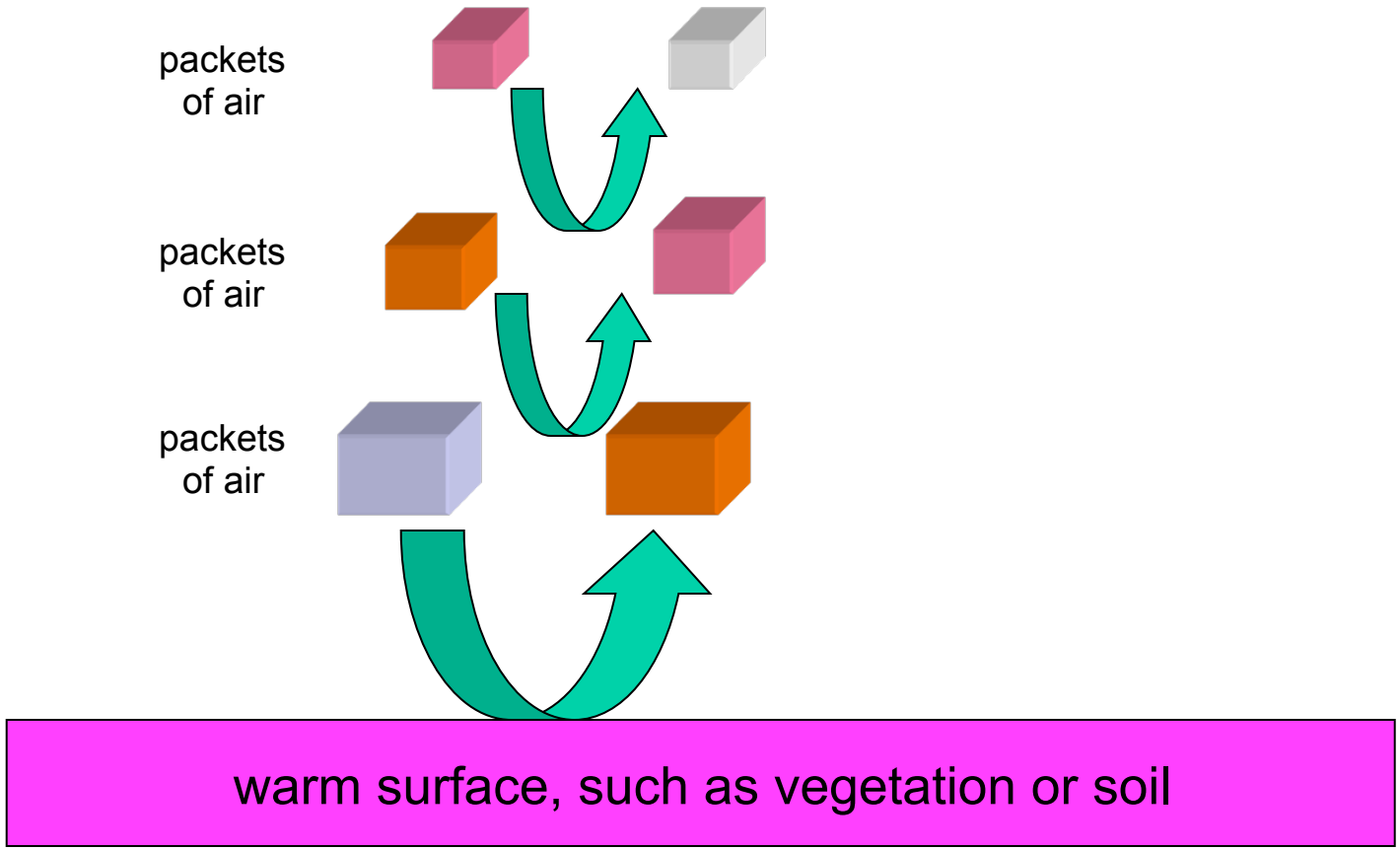
In contrast, the energy dissipation patterns change over the season within a grassland as the soil moisture level draws down



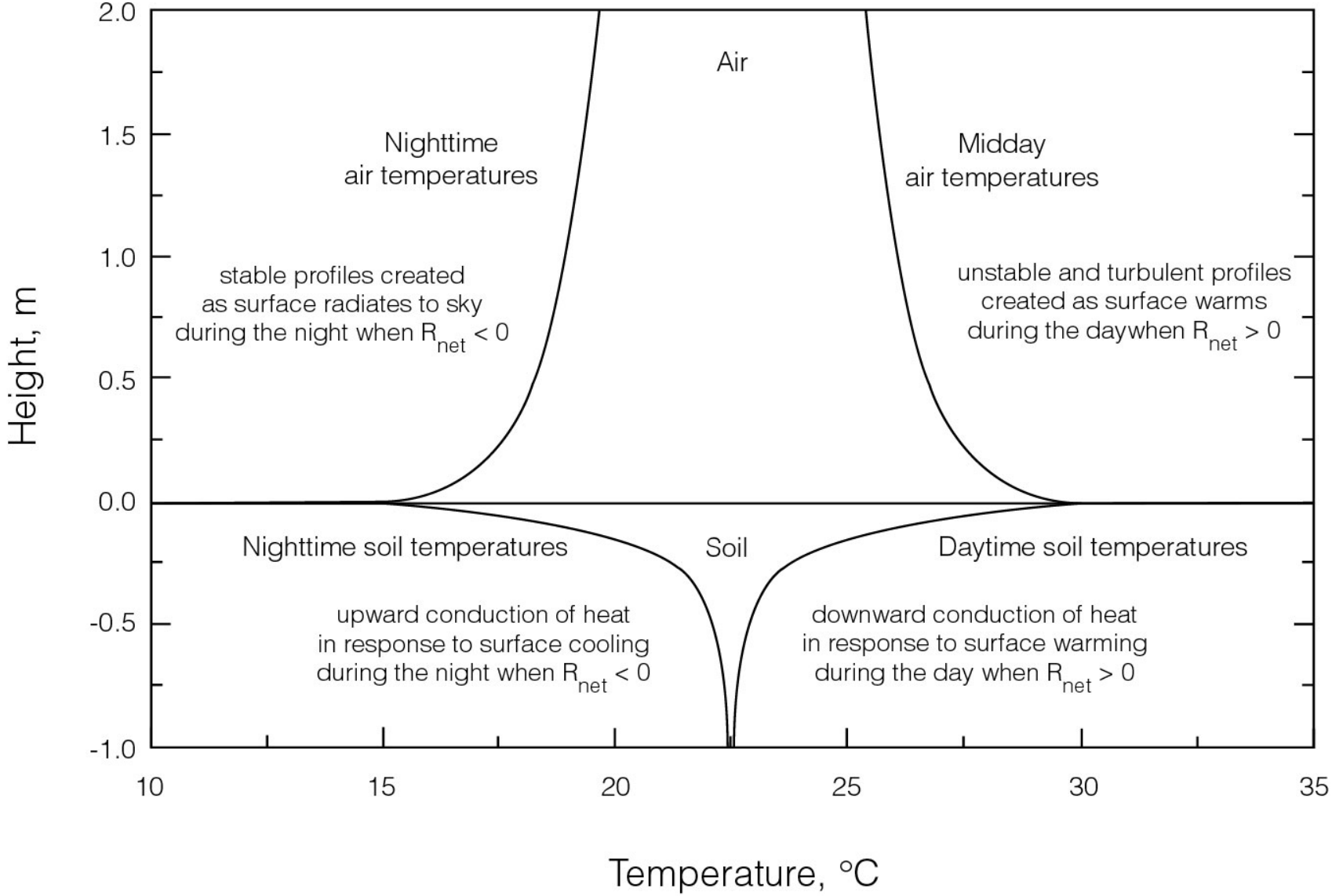

Part 6
Air temperature profiles

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

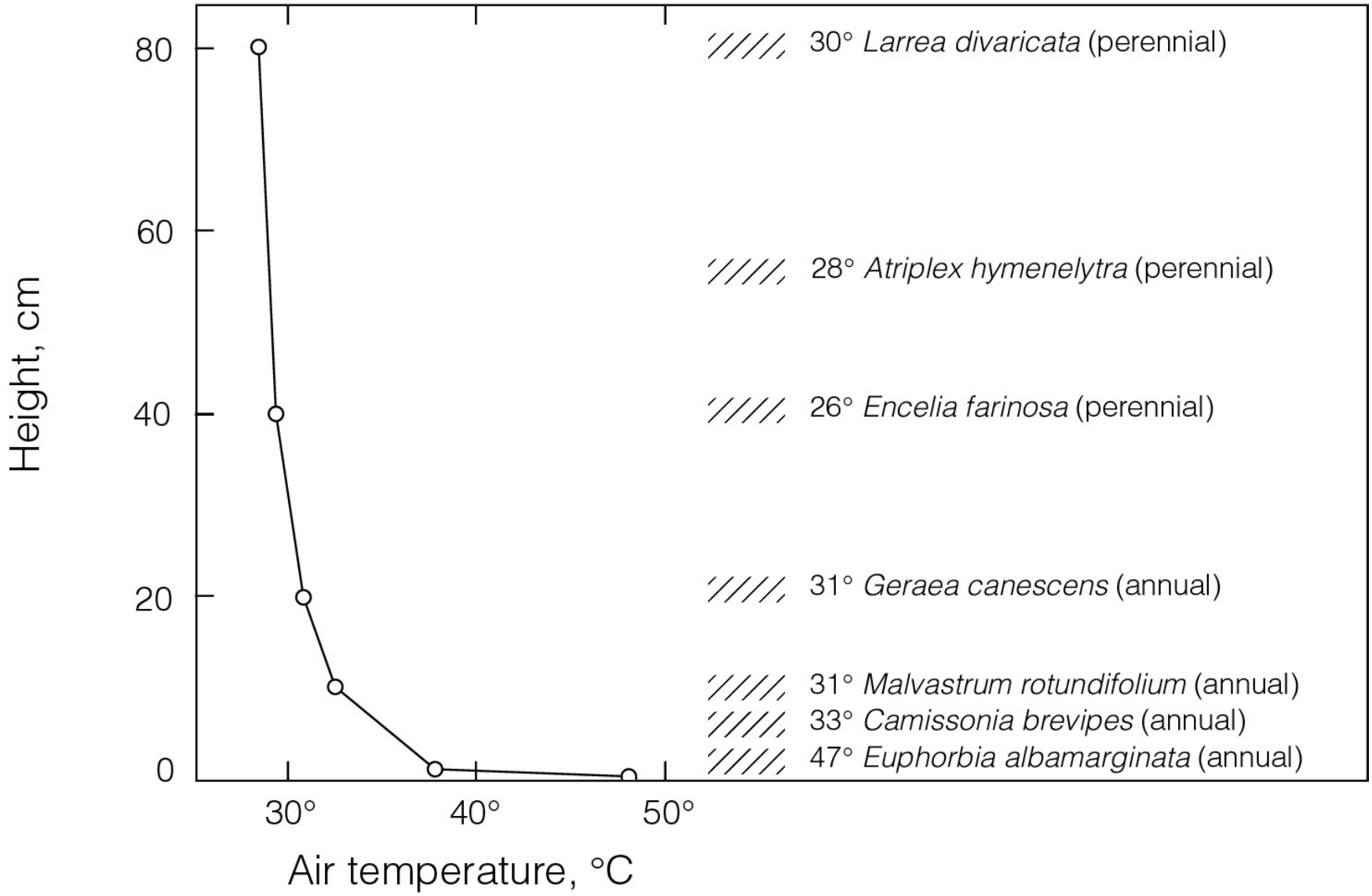


General patterns of microclimatic profiles over bare ground

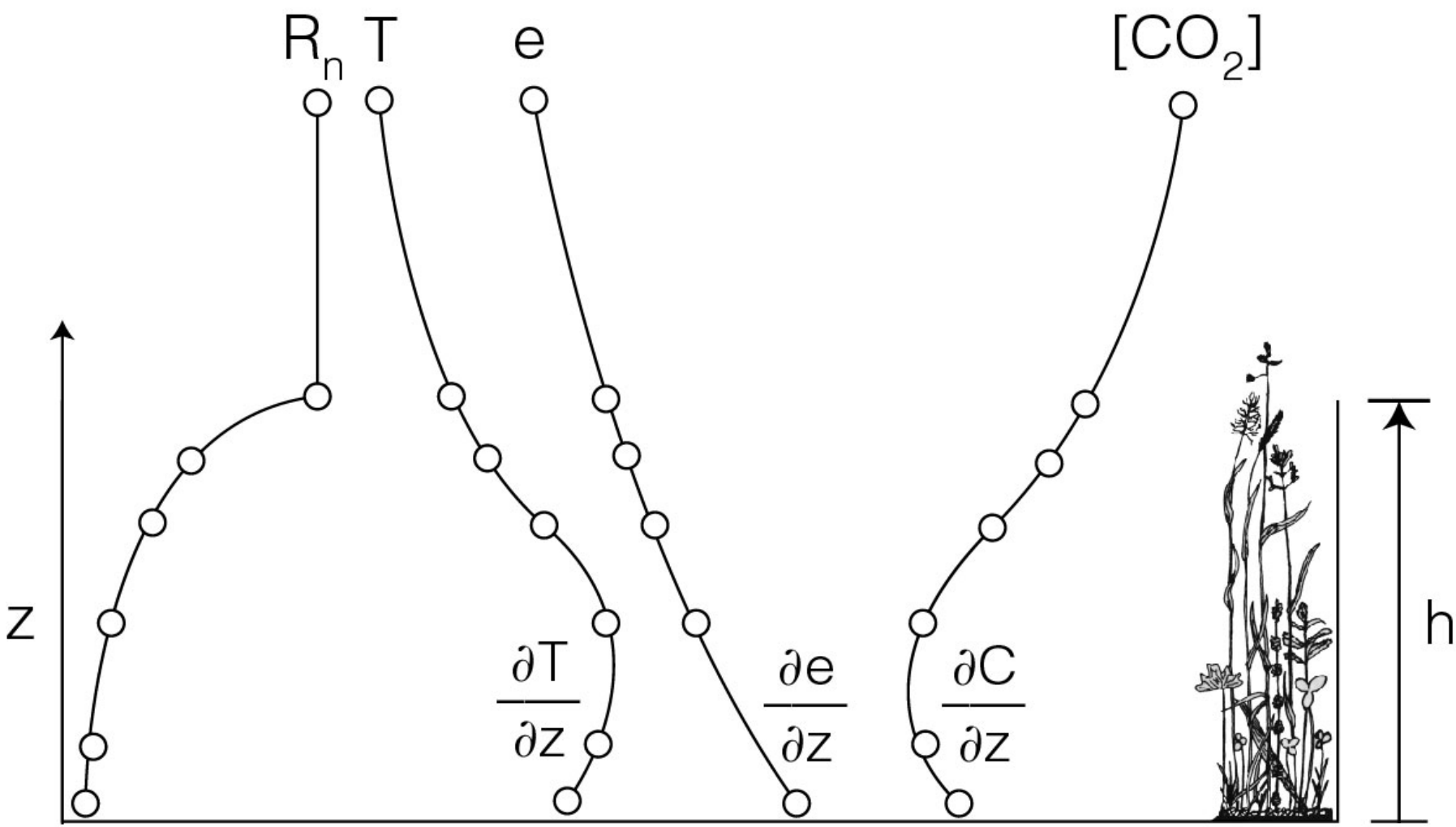


Mohave Desert plants

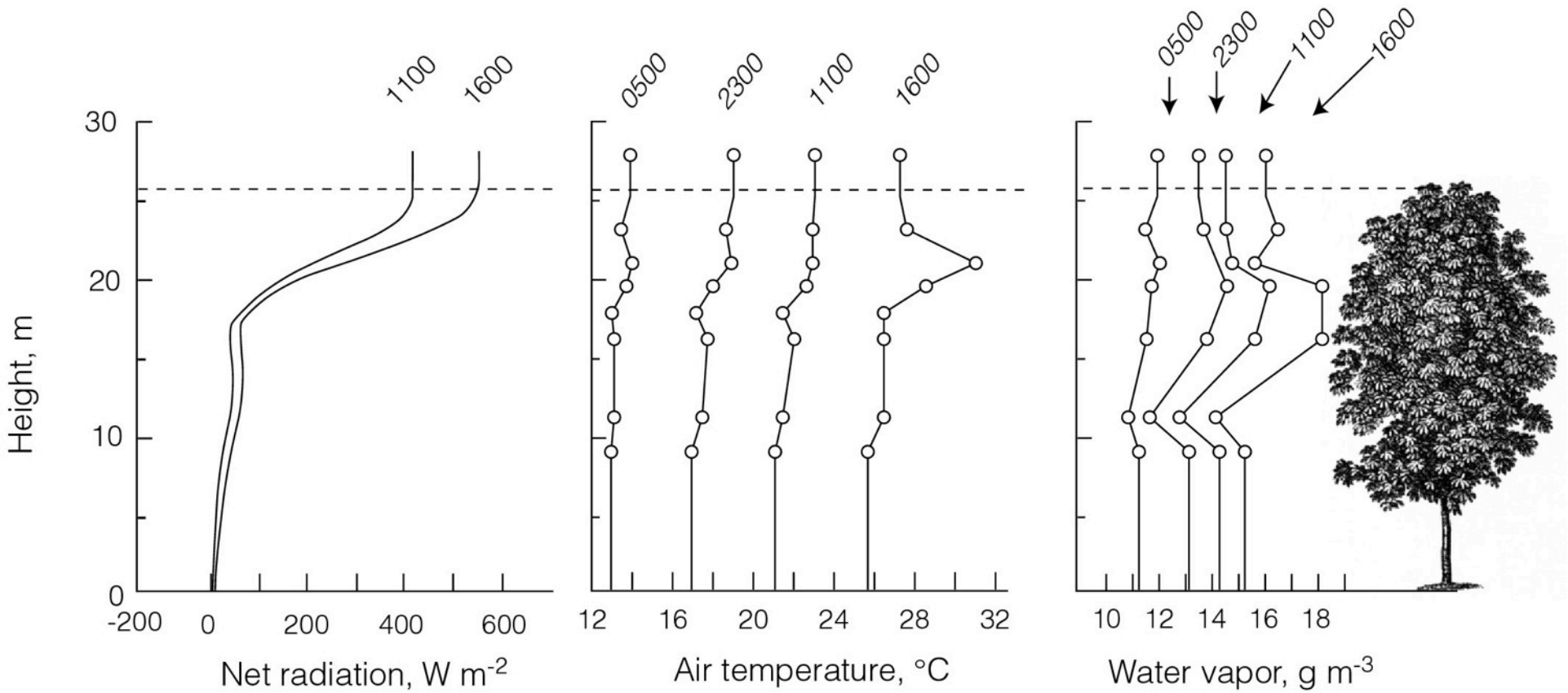
Springtime air and leaf temperature profiles in deserts

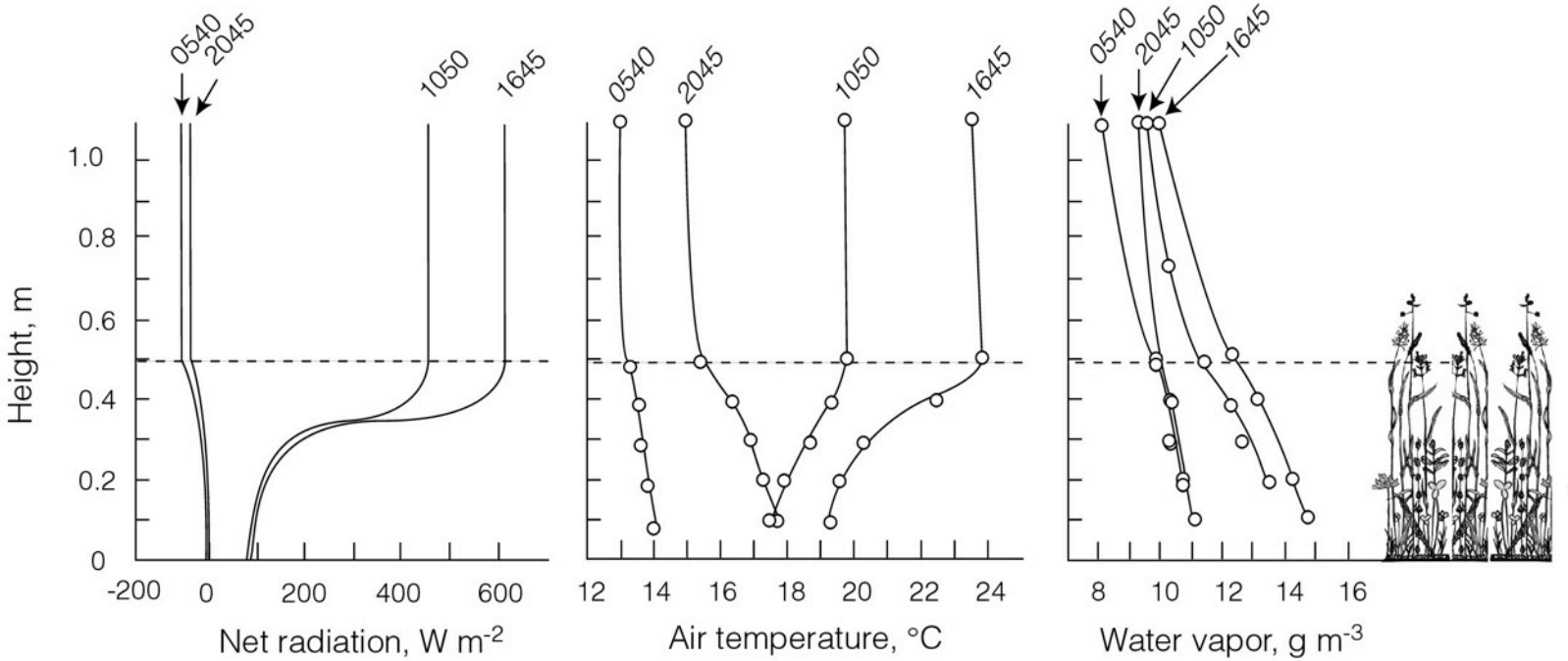


The presence of vegetation alters energy absorption patterns and creates “bulge” air temperature profiles

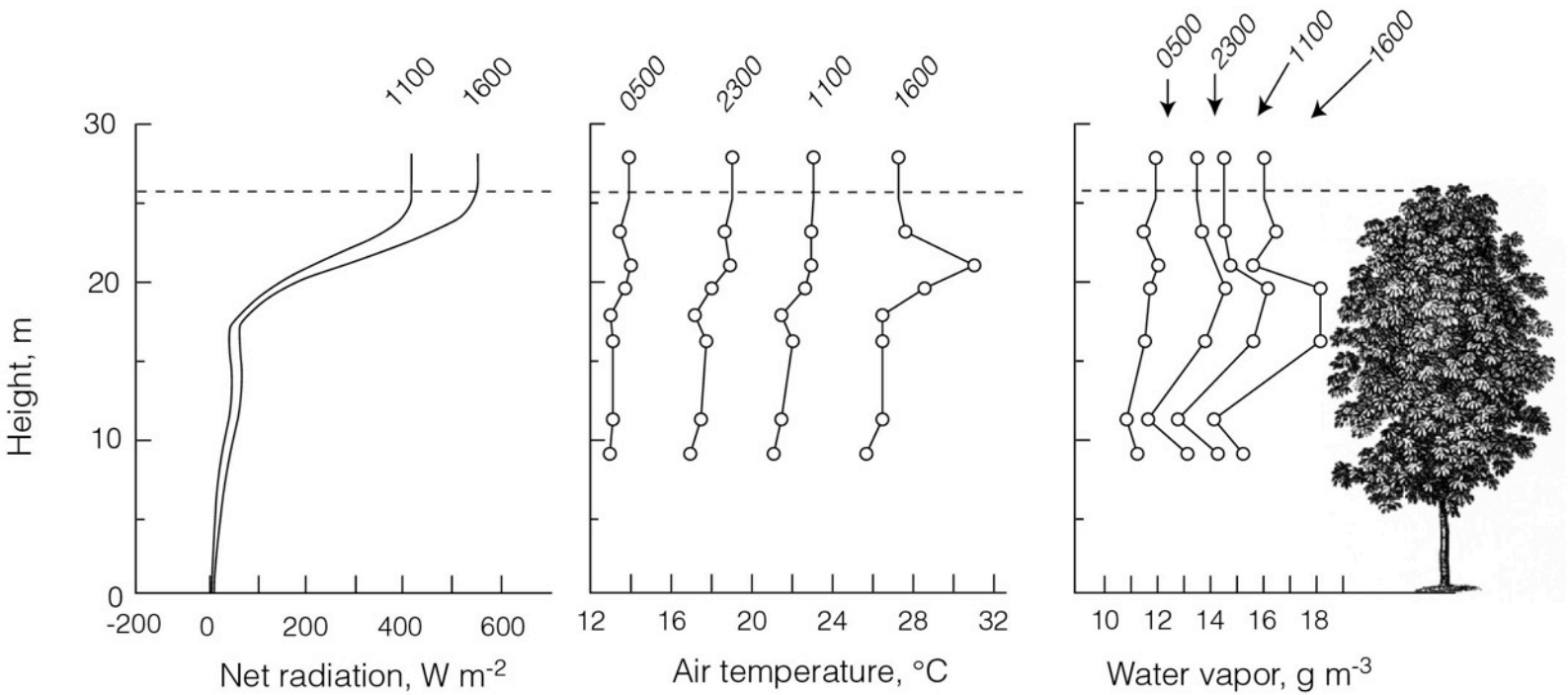


Microclimate profiles with a deciduous forest



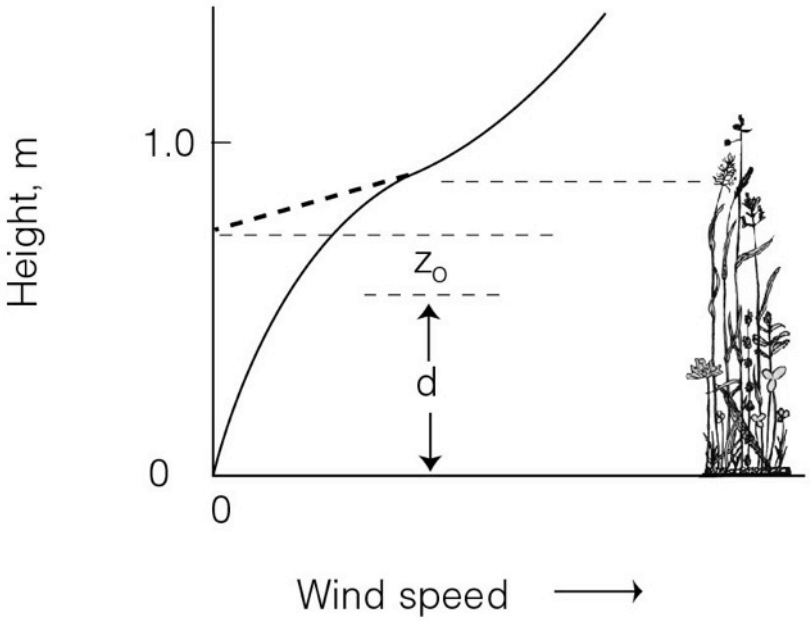


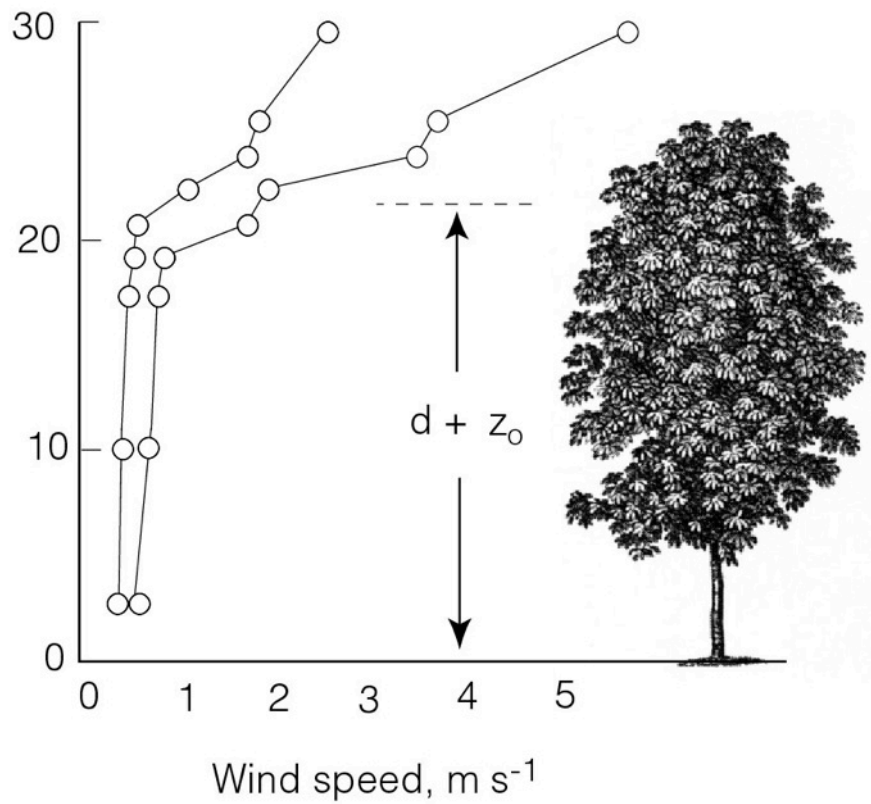
pasture



forest

Wind speed decreases exponentially above the vegetation

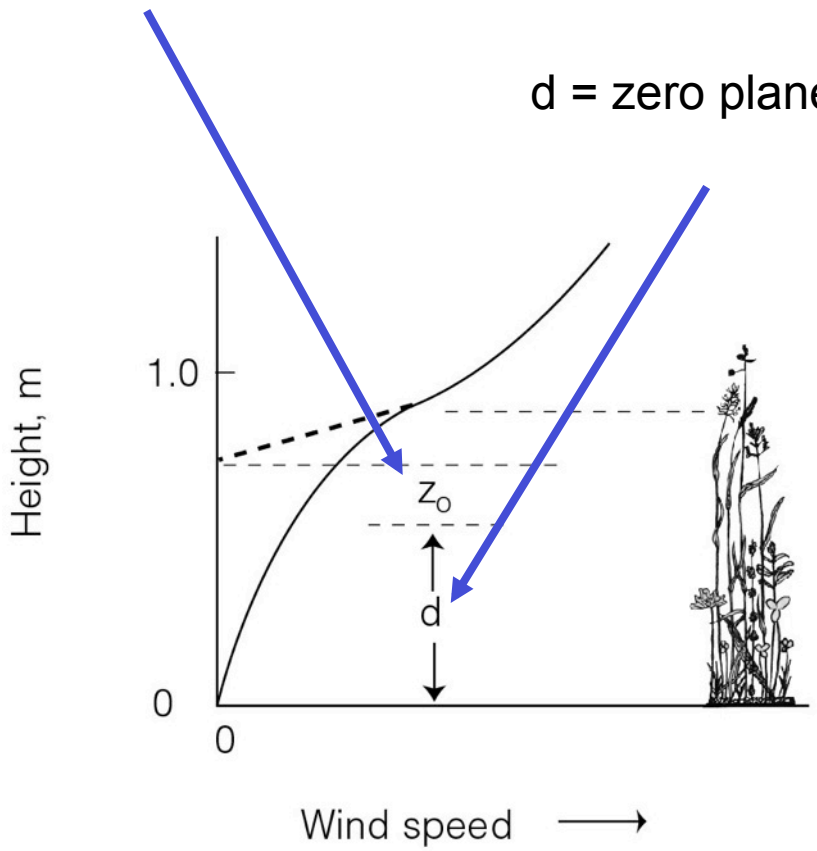


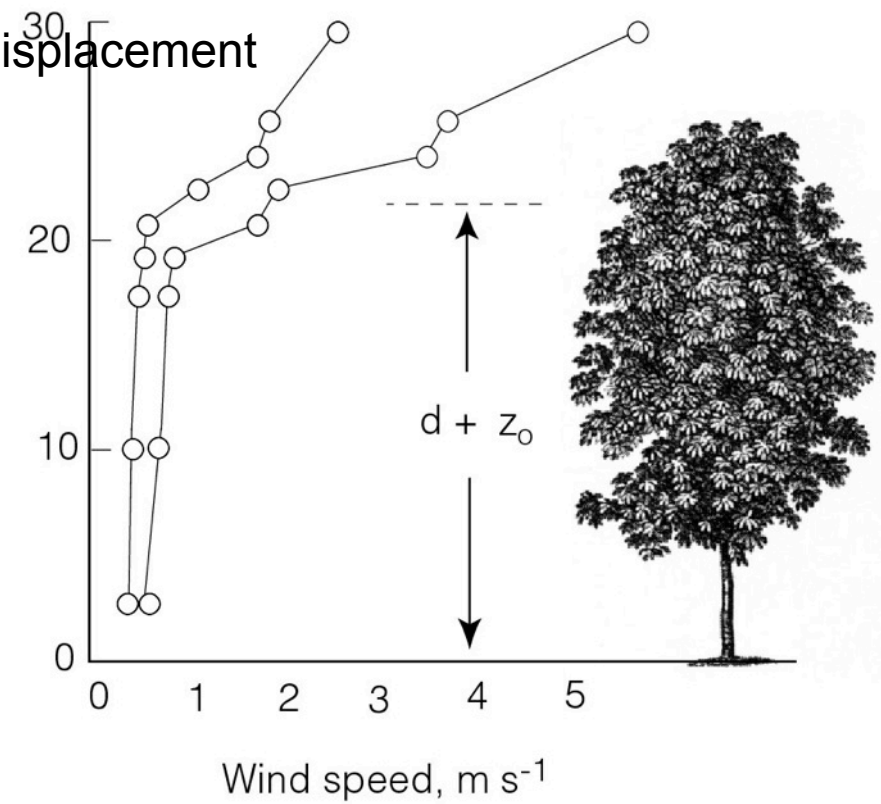


$z_o + d$ = height at which expected exponential decay would have resulted in a wind speed of 0

z_o = roughness parameter

d = zero plane displacement

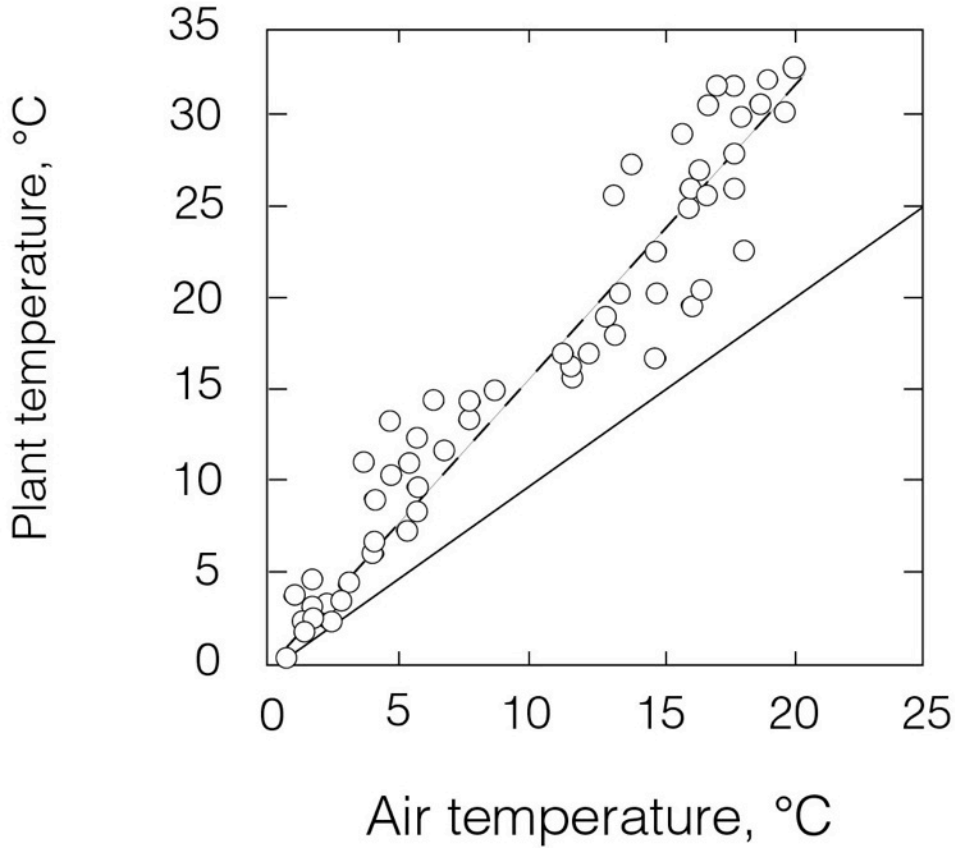


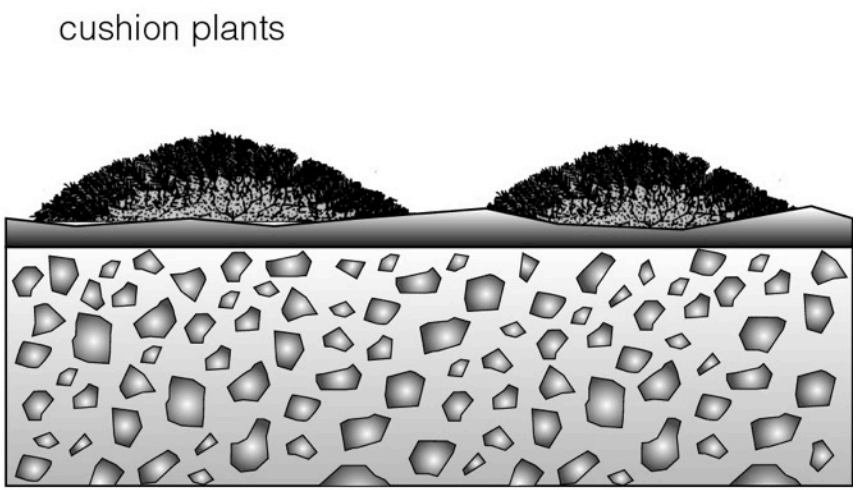


d = position in canopy where half of the momentum is absorbed

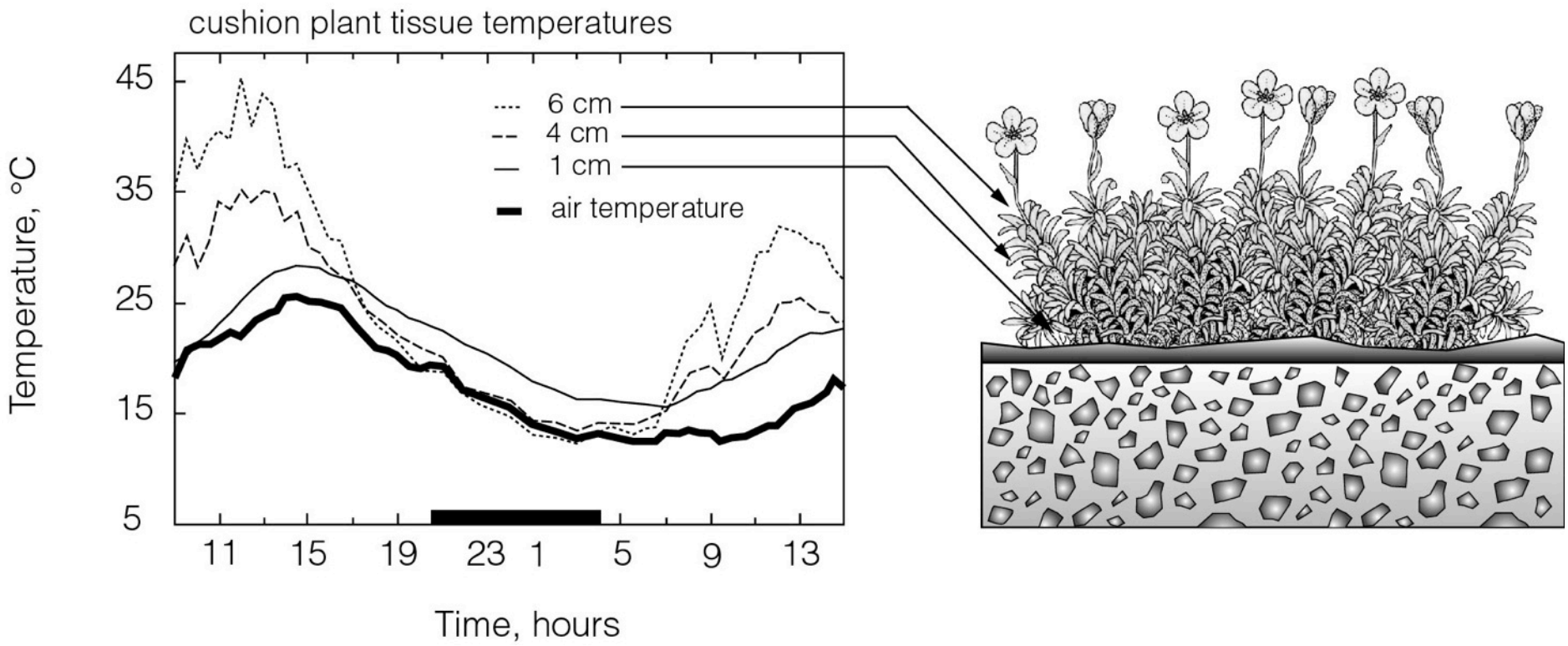
The other temperature extreme … cushion plants from the alpine tundra

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



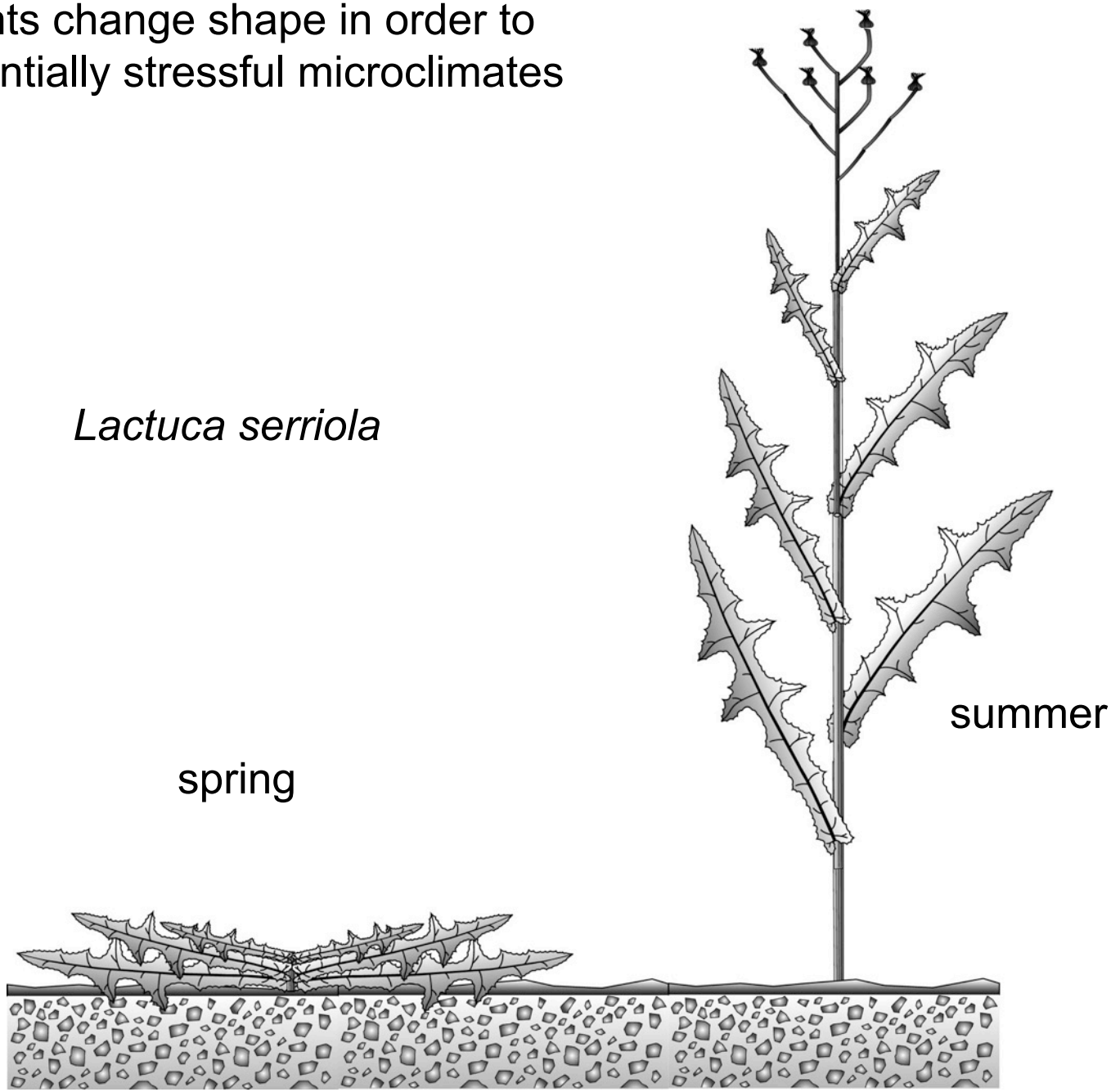


Tightly-packed plants in the alpine tundra experience reduced wind speeds and have elevated temperatures



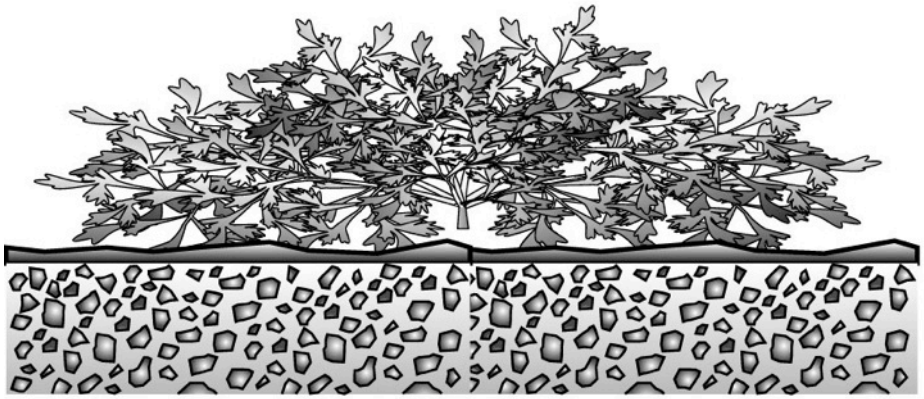
Some plants change shape in order to avoid potentially stressful microclimates

Lactuca serriola

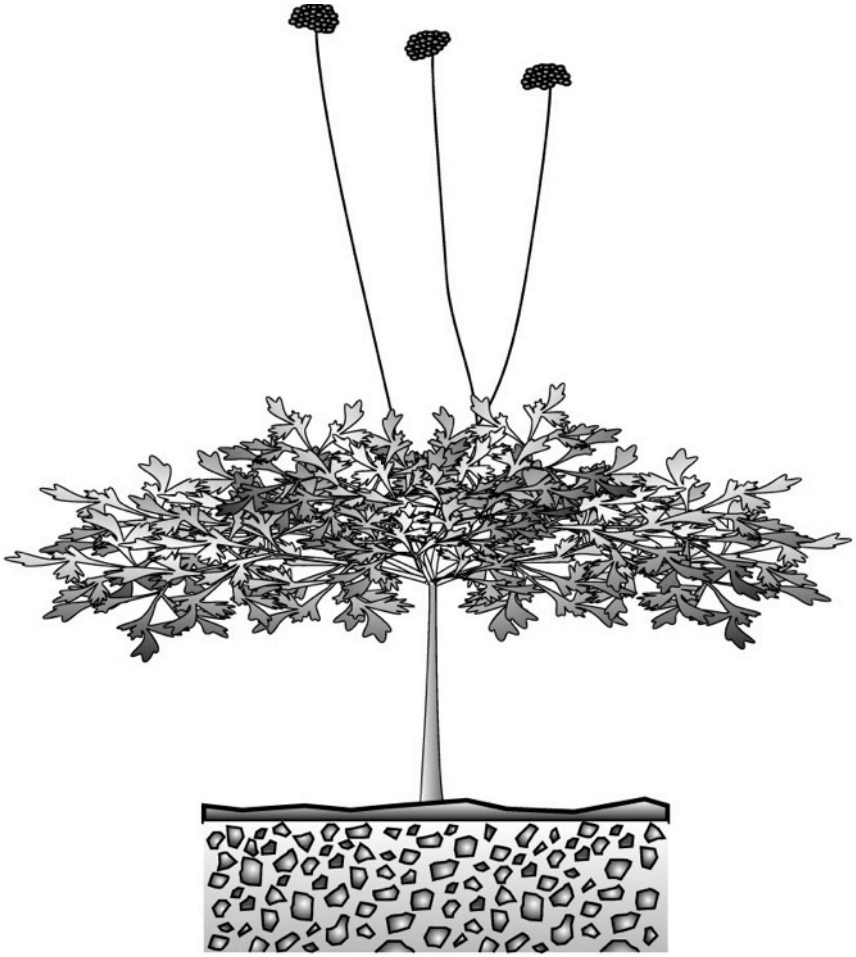


Some plants change height in order to avoid potentially stressful microclimates

Cymopterus longipes

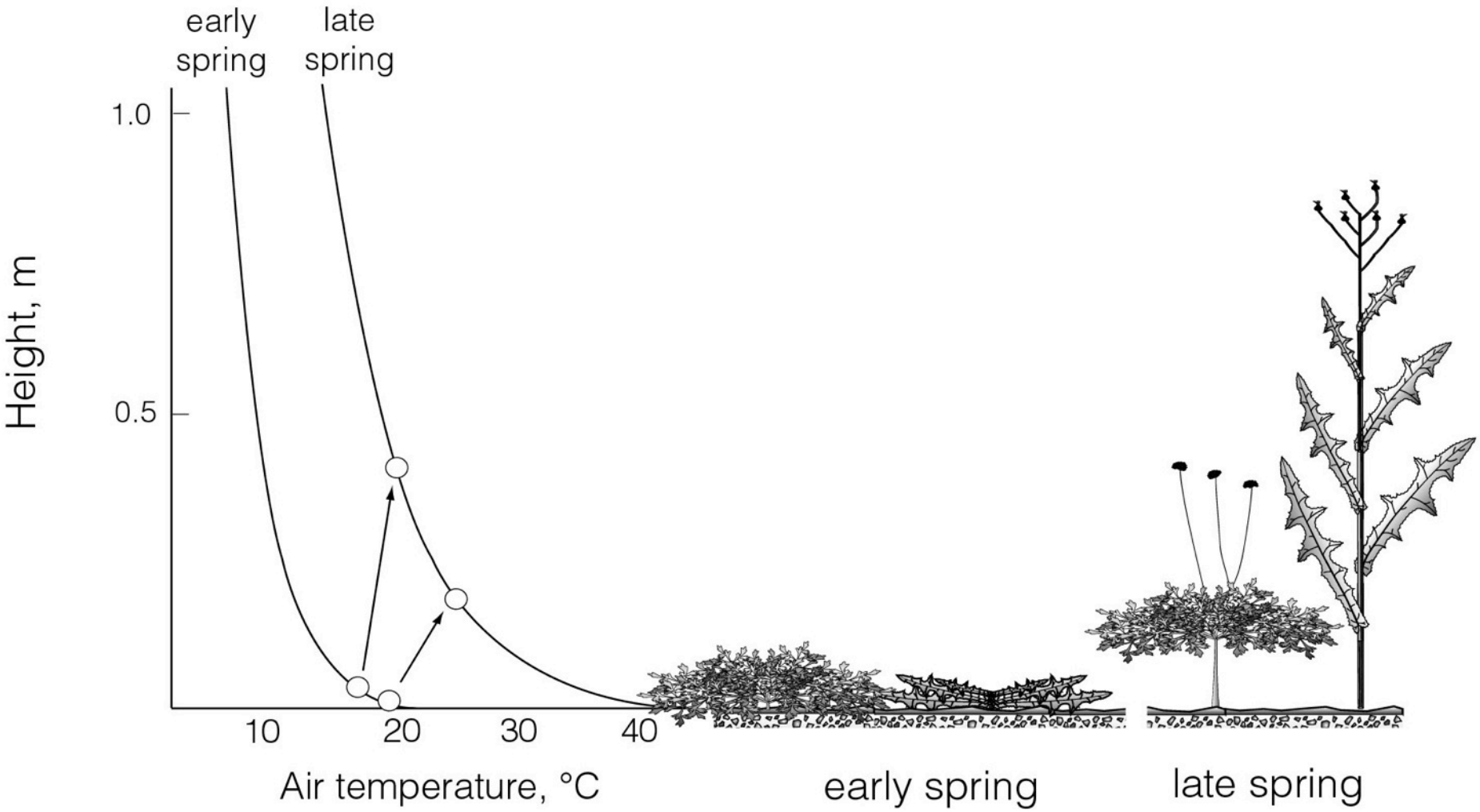


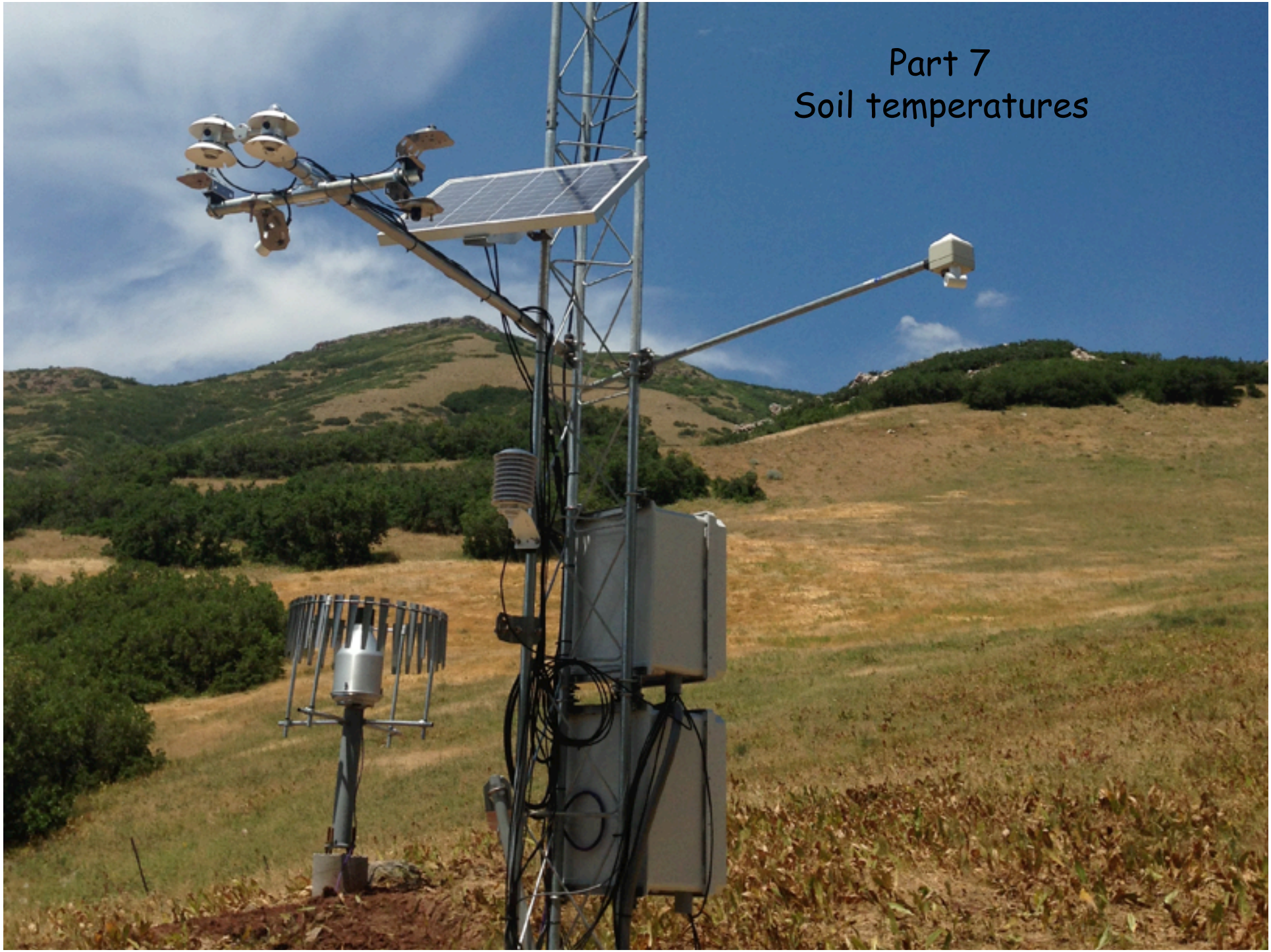
early spring



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

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

soil temperature at depth z

D is damping depth

Soil damping depth

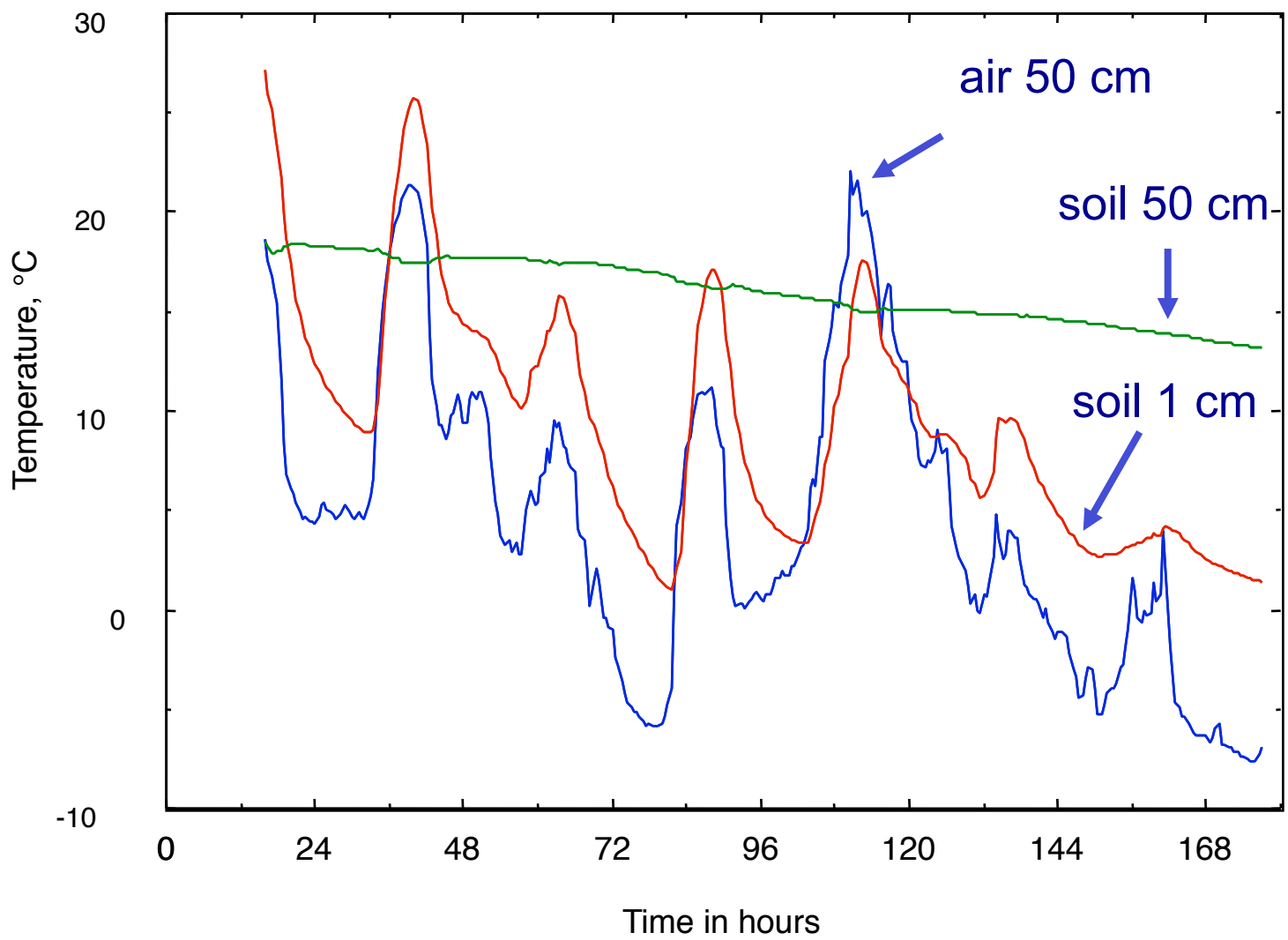
depth in soil required to see a 1/e reduction in daily amplitude

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

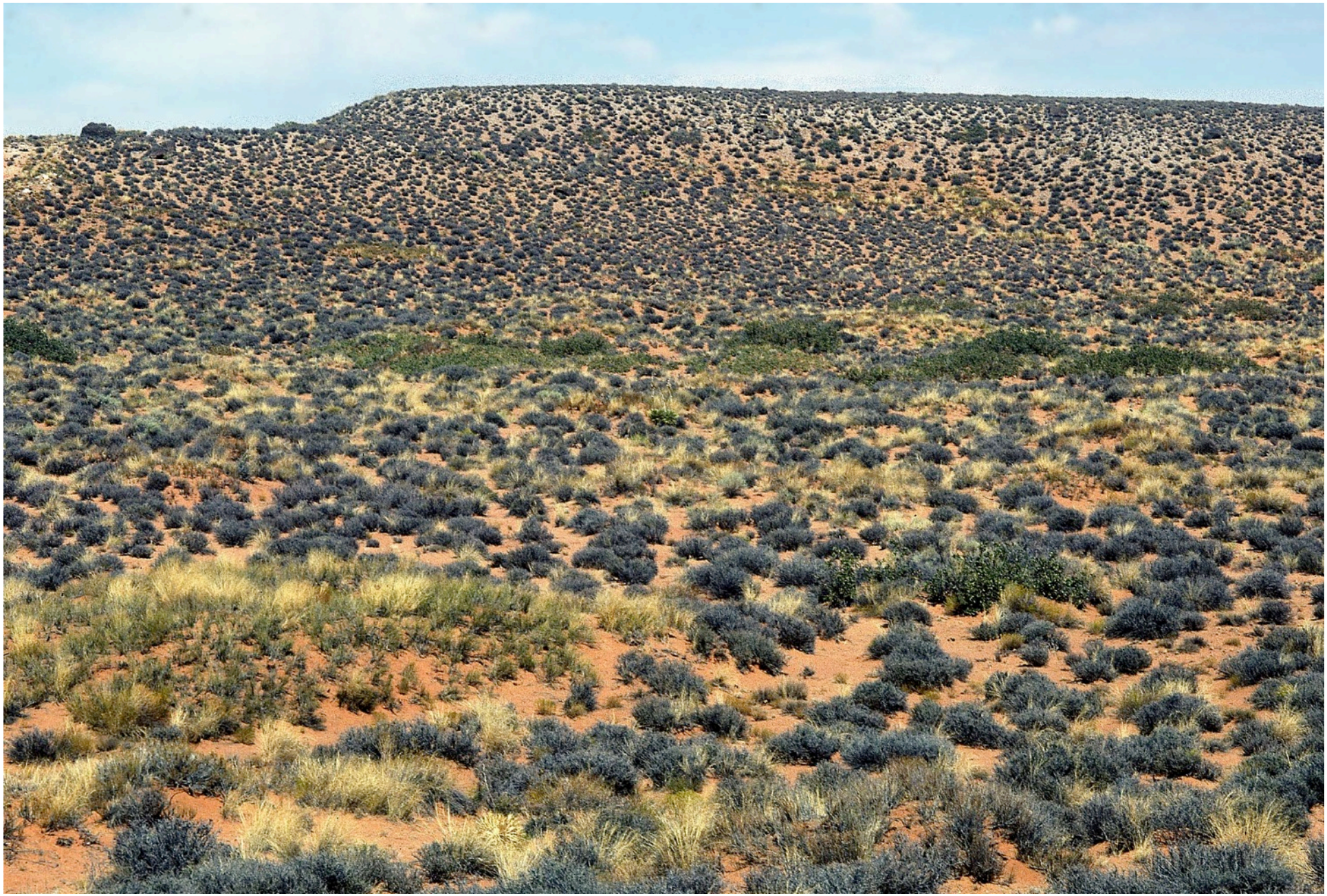
D = 0.06 m dry soil
= 0.15 m wet soil

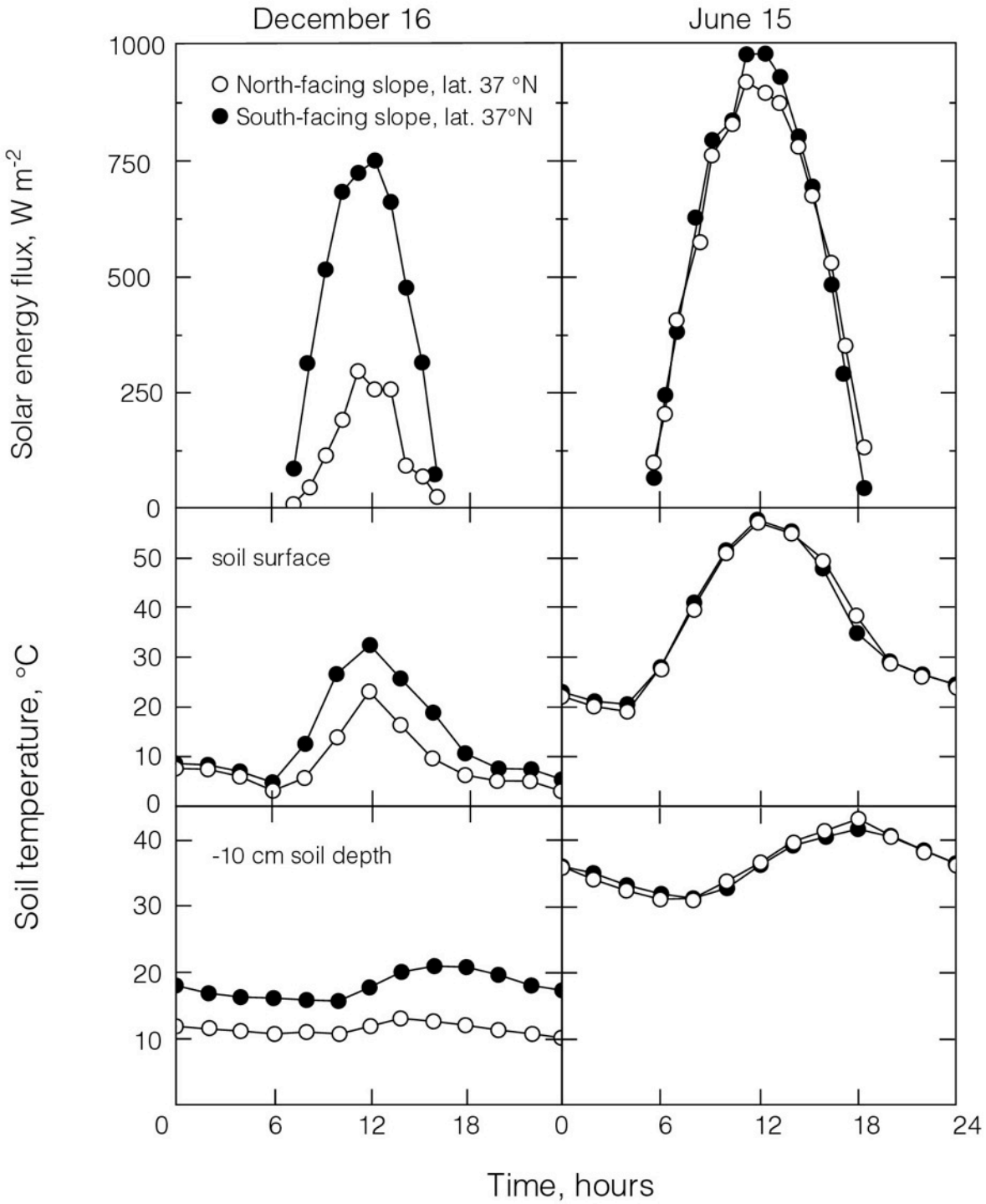
D on an annual basis is ~ 19x higher than on a daily basis

Class observations of soil temperature with depth



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