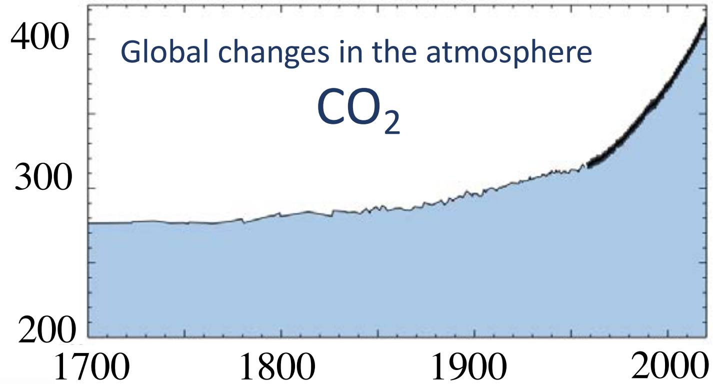
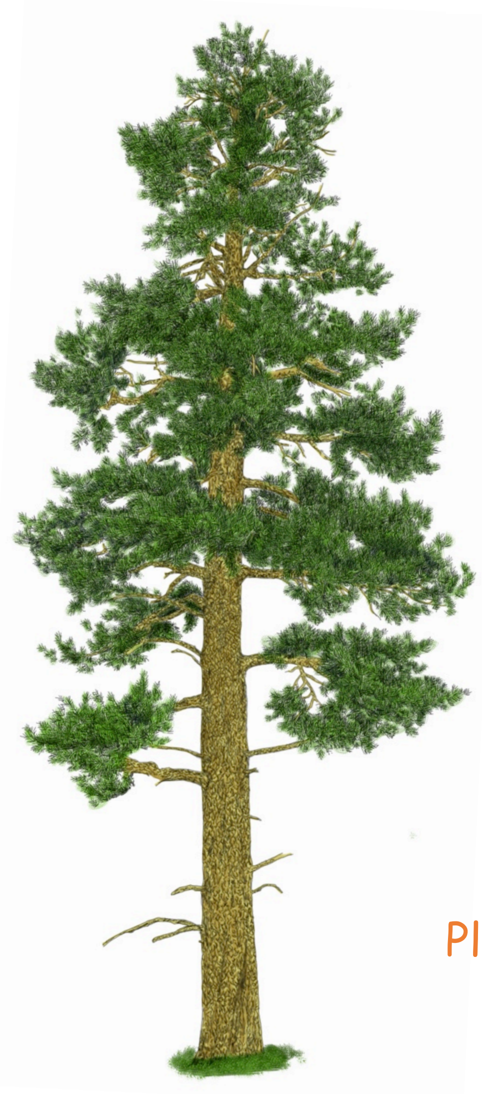


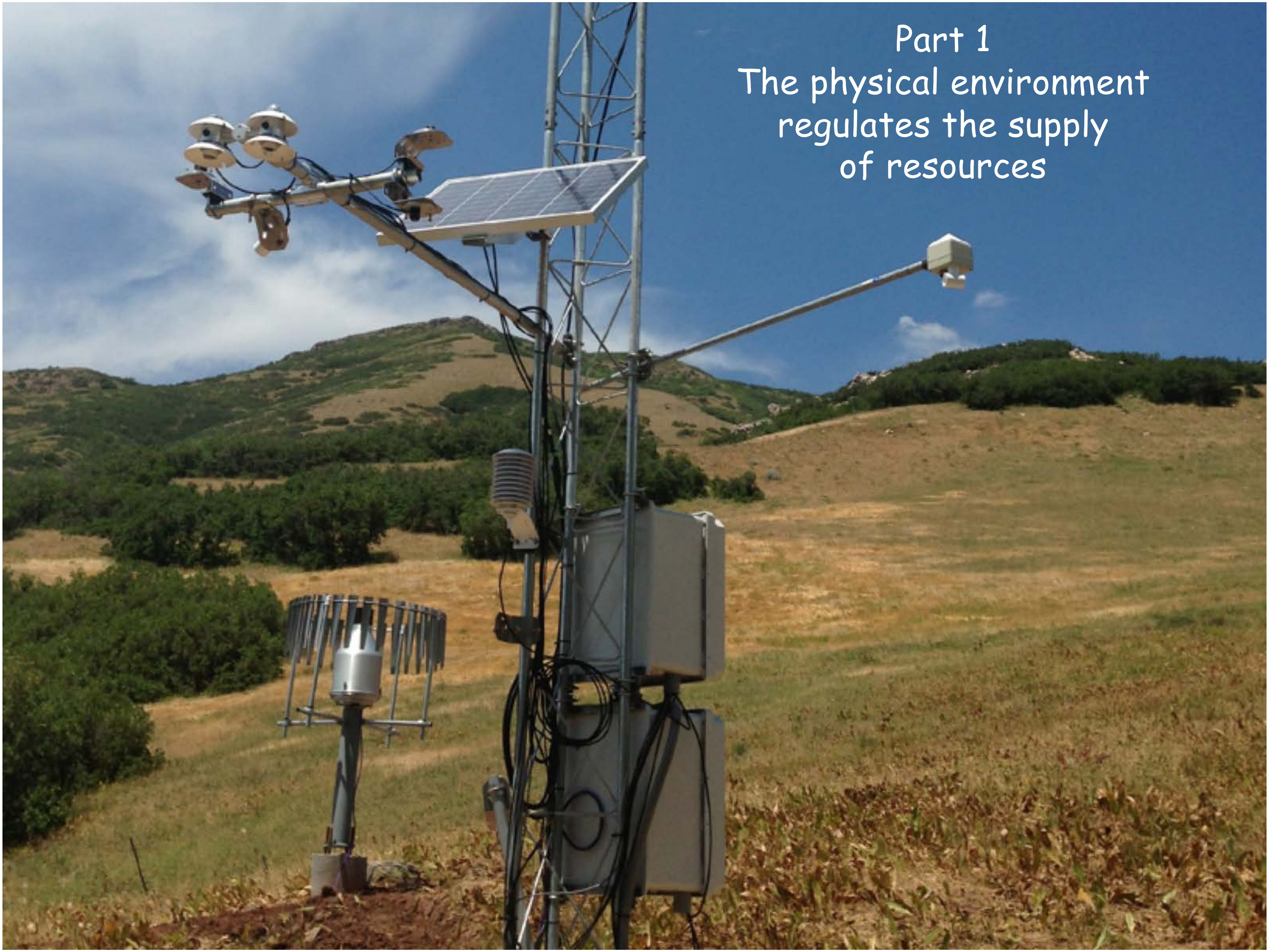


Topic 8a

Macroclimates And Microclimates

Plant Ecology in a Changing World

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

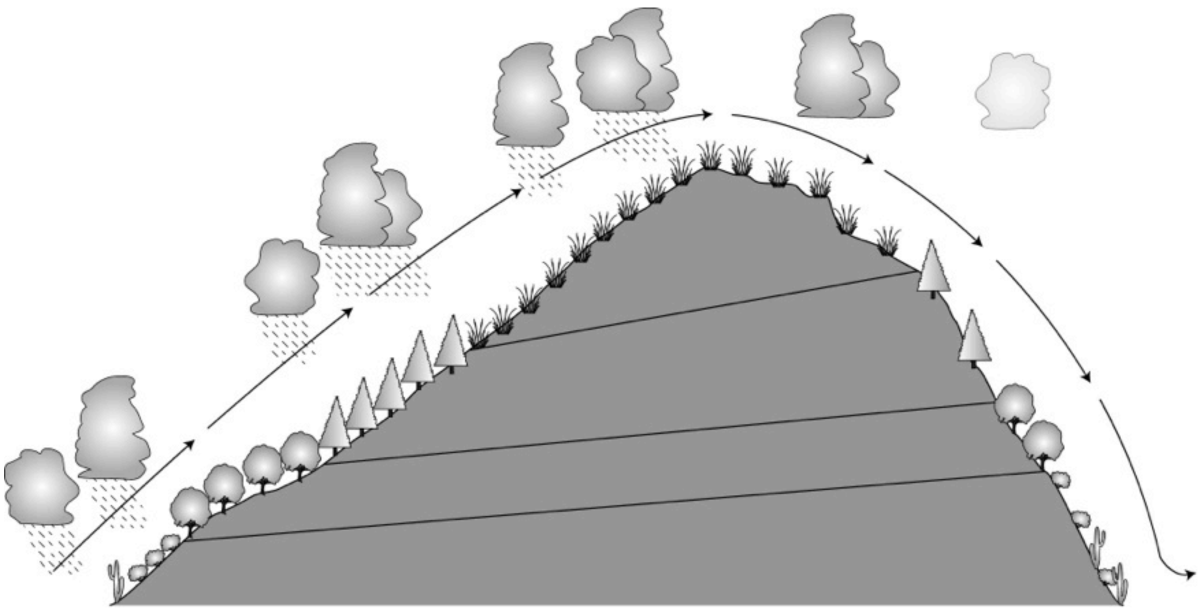

Part 1
The physical environment
regulates the supply
of resources

The physical environment regulates the supply of resources

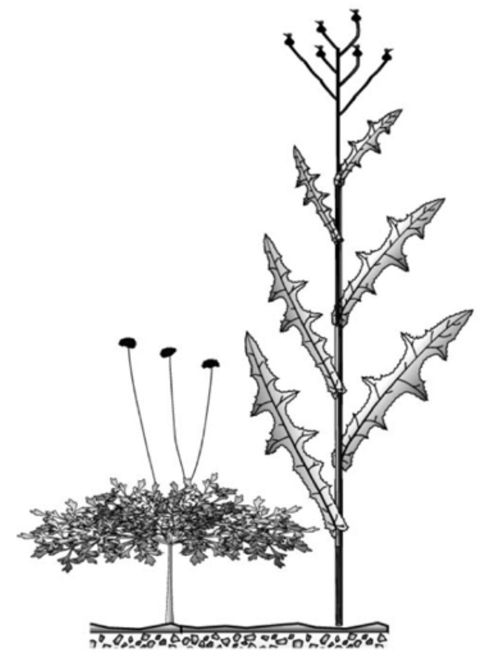
- macroclimate versus microclimate
- the biological microclimate is driven by solar and terrestrial energy inputs
- incoming solar energy is converted to heat and dissipated as reradiation, convection, or transpiration
- vegetative structure contributes to establishing microclimate heterogeneity

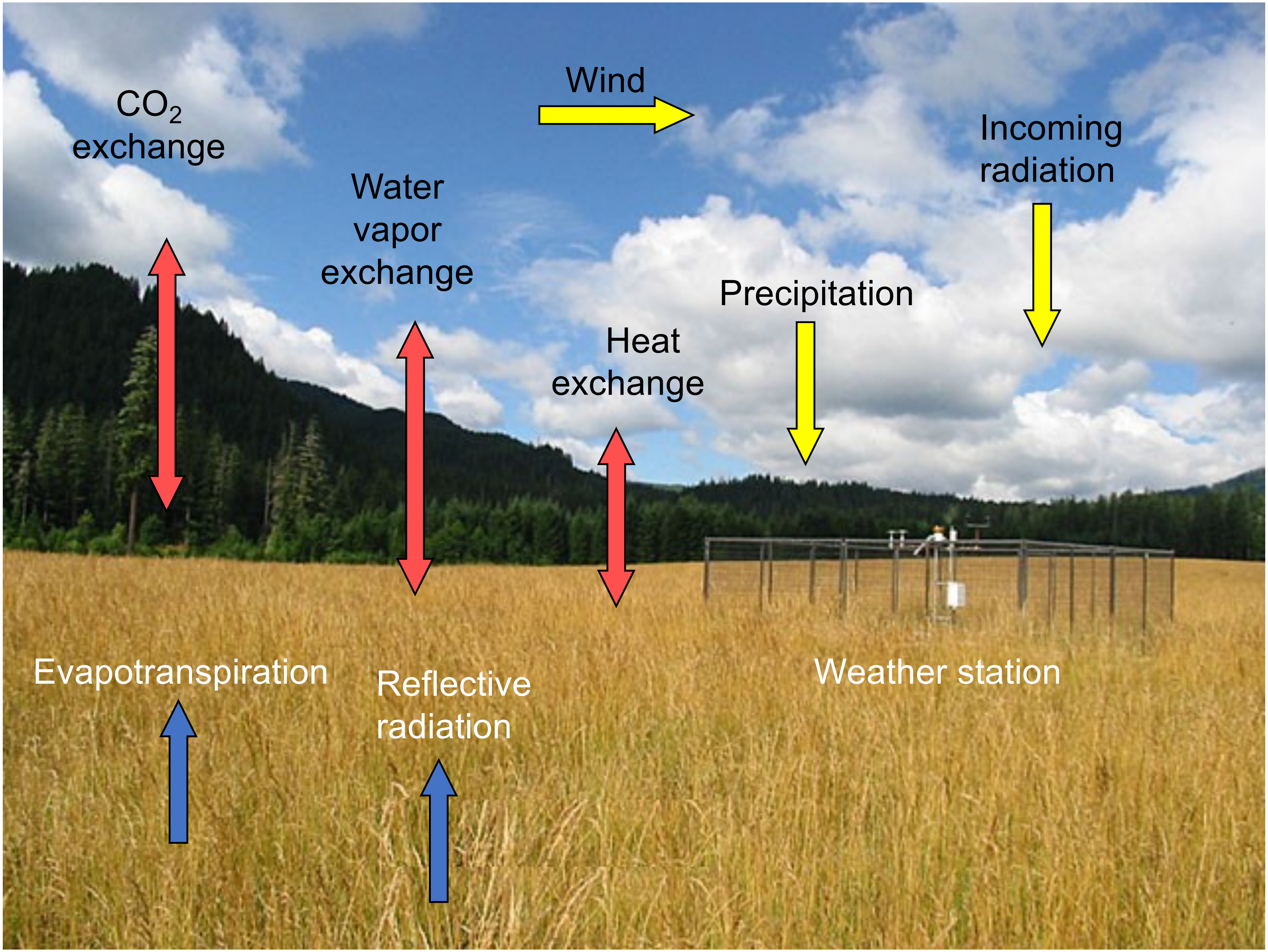
The distinction between macroclimate and microclimate is a matter of scale

macroclimate



microclimate





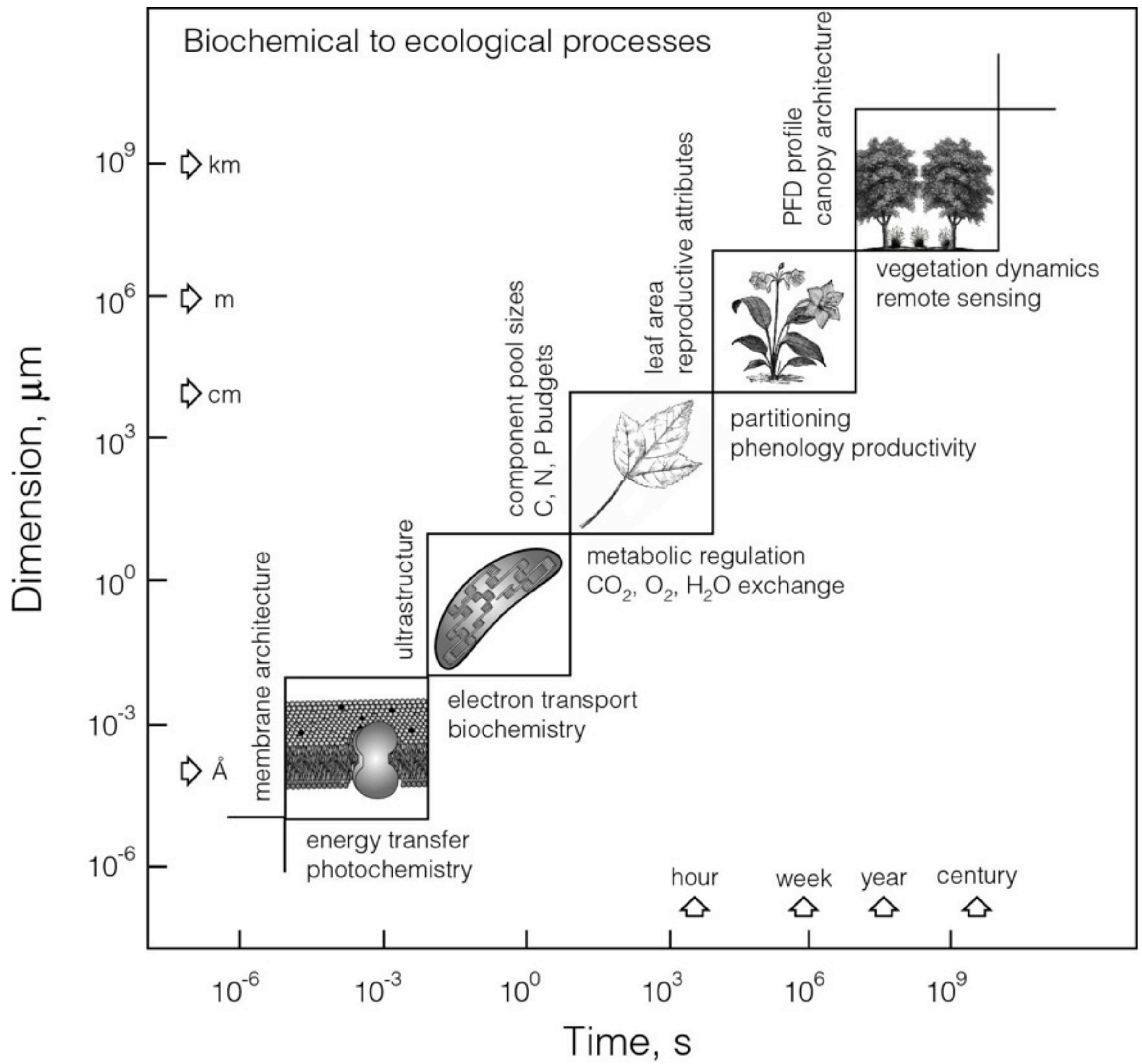
CO_2 exchange
Wind
Incoming radiation
Water vapor exchange
Precipitation
Heat exchange
Evapotranspiration
Reflective radiation
Weather station

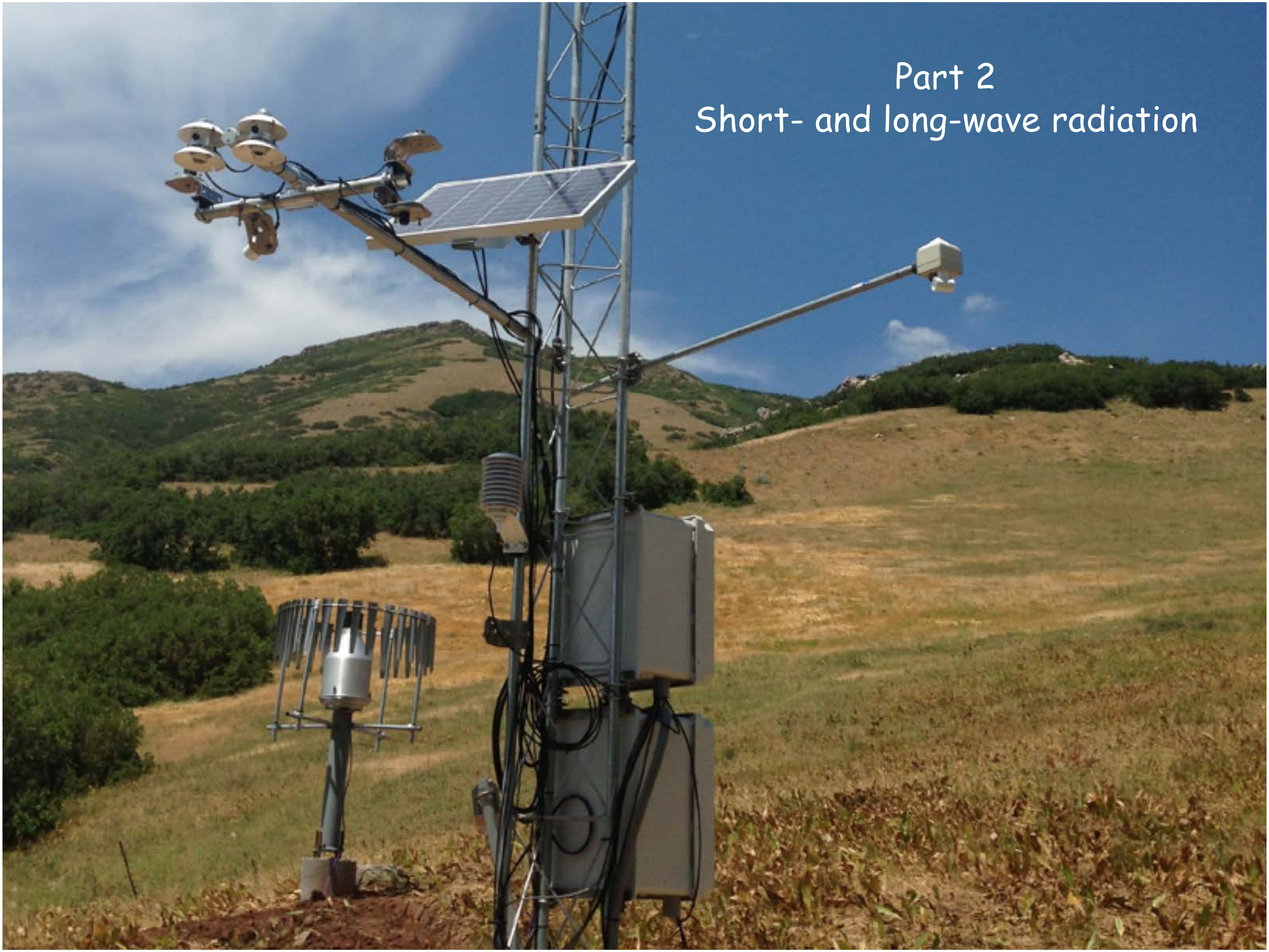
The physical environment impacts plant performance

- physical environment supplies resources (water, nutrients, temperature, humidity, sunlight)
- physical environment temporally modulates plant activities (temperature, sunlight, daylength)
- physical environment imposes stresses (water, nutrients, temperature, humidity, sunlight)

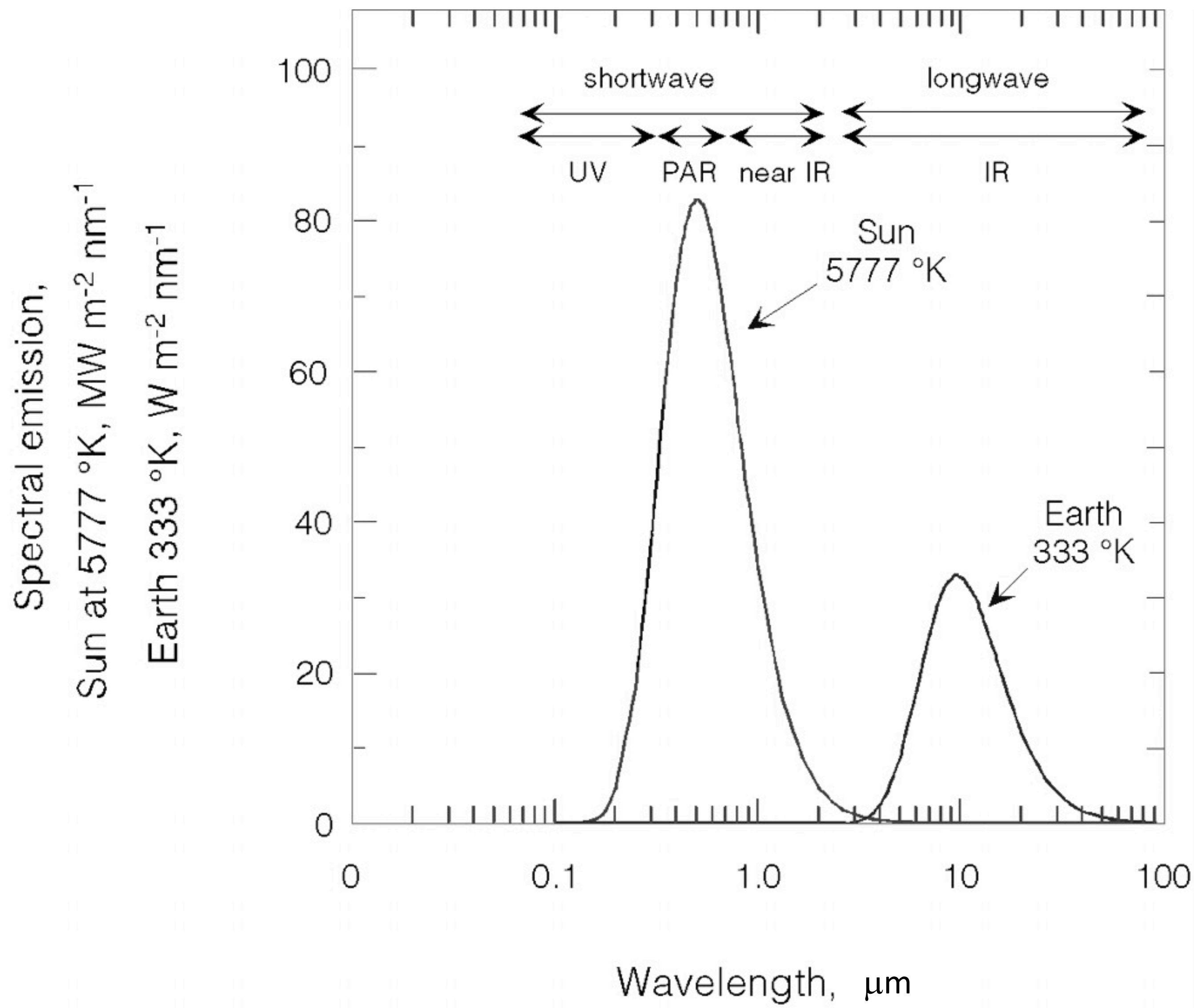
Recognizing the temporal scales of environmental measurements is critical

We must recognize that dynamics and variations in the physical environment and their impacts on plants occur over different time scales.




Part 2
Short- and long-wave radiation

Variations in the biological microclimate are driven by differences in the inputs of both solar radiation and terrestrial radiation



Blackbody Radiation Law - all objects above 0°K emit radiation

$$E = \varepsilon \sigma T^4$$

energy emitted

emissivity or efficiency of emission

Stephan-Boltzman constant $5.67 \times 10^{8}\ W\ m^{-2}\ K^{-1}$

temperature of the object, °K

The emissivity of biological materials and of O-containing materials is high

Oxidized inorganic materials are strong blackbodies

emissivity values, %

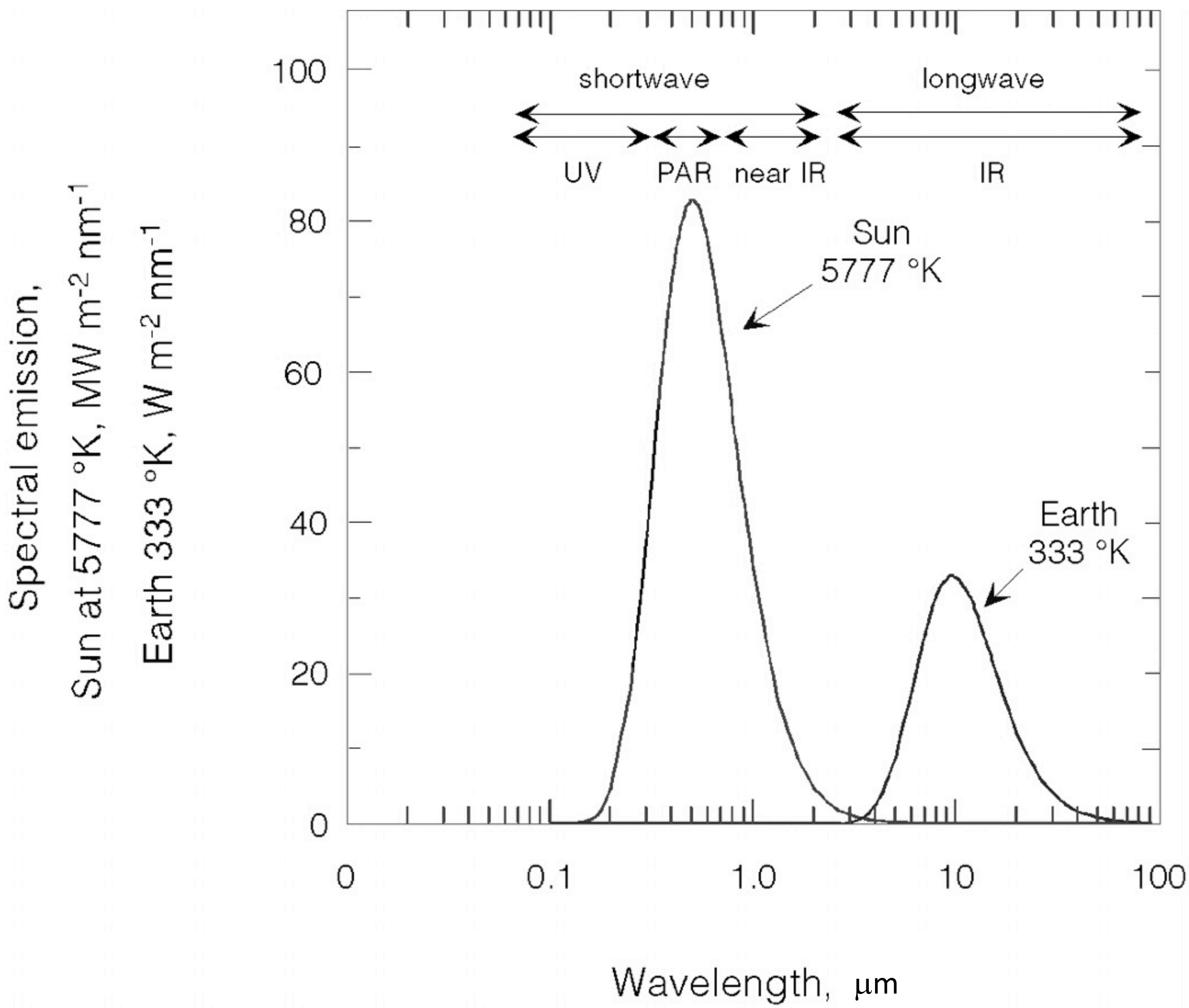
polished Al	4
polished Cu	5
copper oxide	78
cast iron	65
brick	93
quartz	93
water	95

Biological materials are strong blackbodies

emissivity values, %

cotton leaves	97
oak leaf	97
sunflower leaf	97

Because of surface temperature differences between the Earth and sun, there is no overlap in the spectral emission patterns



The sun is a point source

Terrestrial objects are not point sources

.. therefore orientation influences the amount of sunlight received

.. therefore orientation has limited influence on the amount of infrared received

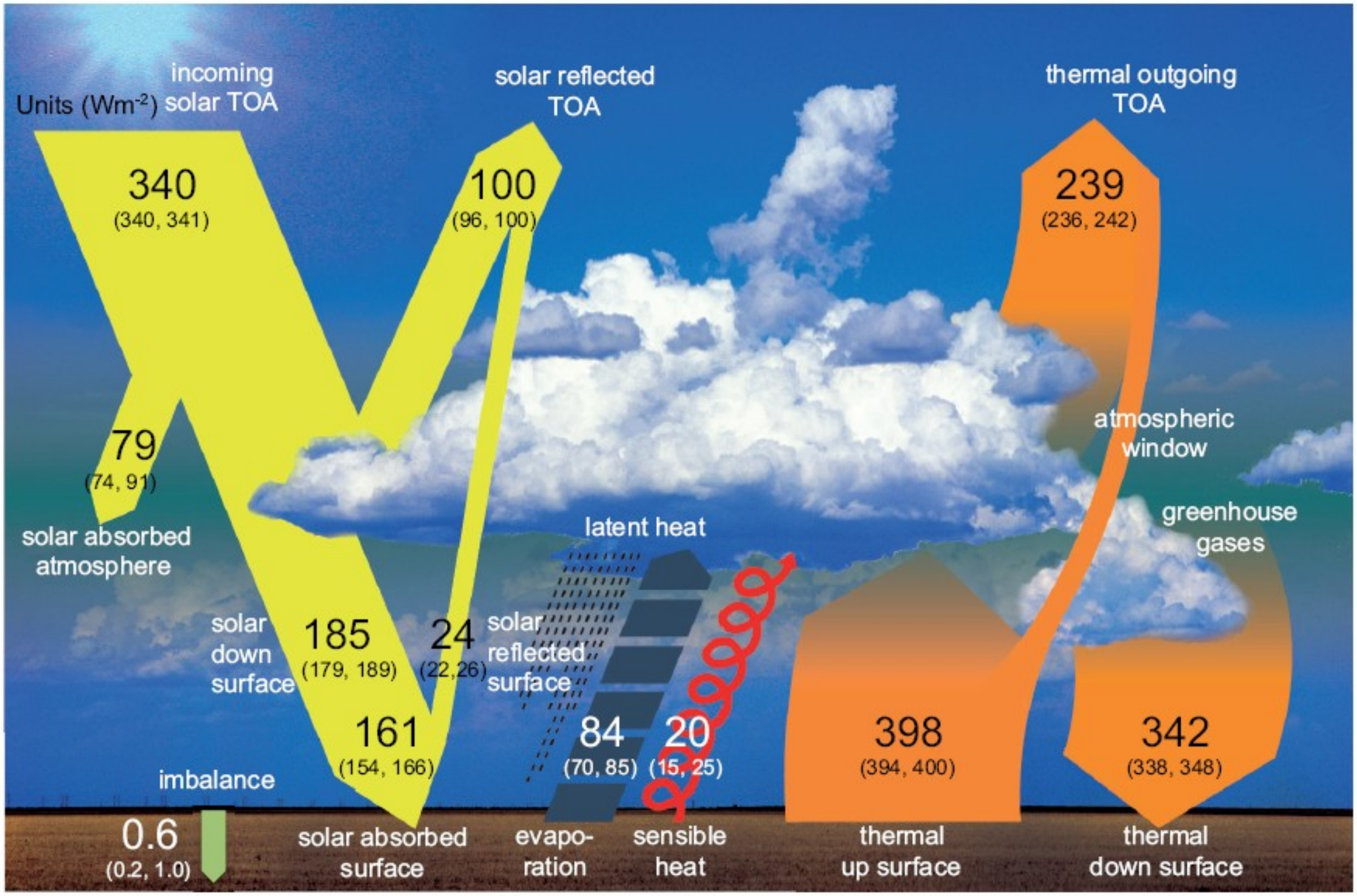
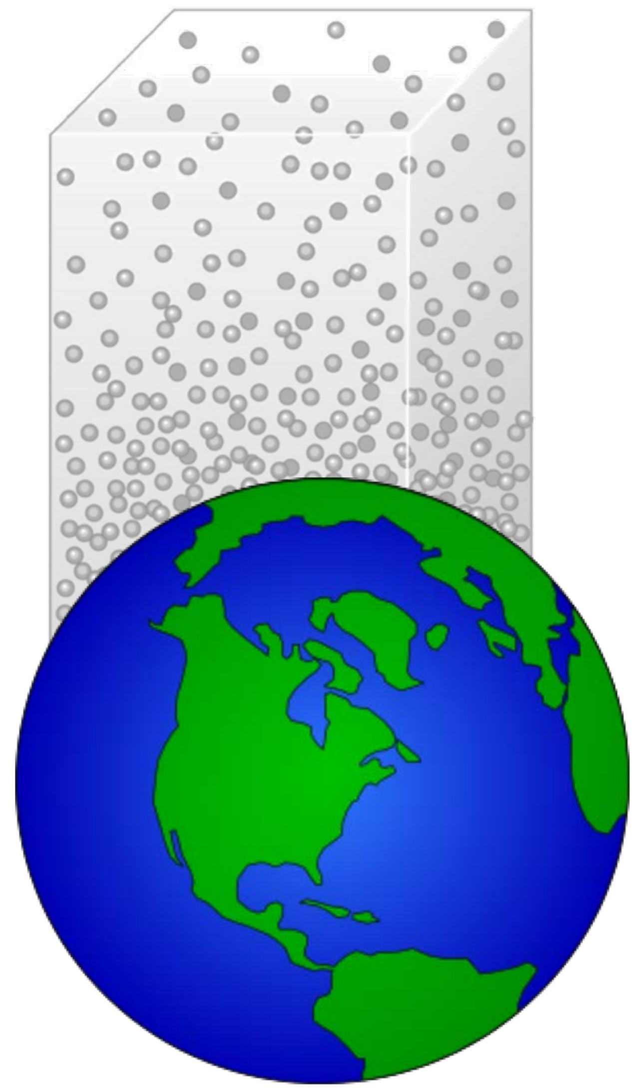


Figure 2.11: | Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in W m^{-2}, adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)

http://www.metlink.org/wp-content/uploads/2014/05/2.111.jpg

Unlike biological organisms, the atmosphere (sky) is not a strong blackbody

- the density of absorbing molecules is less that of the soil
- the dominant atmospheric gases (N_2, O_2, Ar) have limited influence of increasing emissivity
- largest component influencing the emissivity of air are the greenhouse gases (CO_2, CH_4, N_2O, and H_2O)
- $\varepsilon_{air} = 0.06e0^{0.5} + 0.53$ (e = vapor pressure)



Short- and long-wave radiation originates from different sources

short-wave radiation
(sun)

- ultraviolet (100 - 400 nm)
- visible (400 - 700 nm)
- near infrared (700 - 4,000 nm)

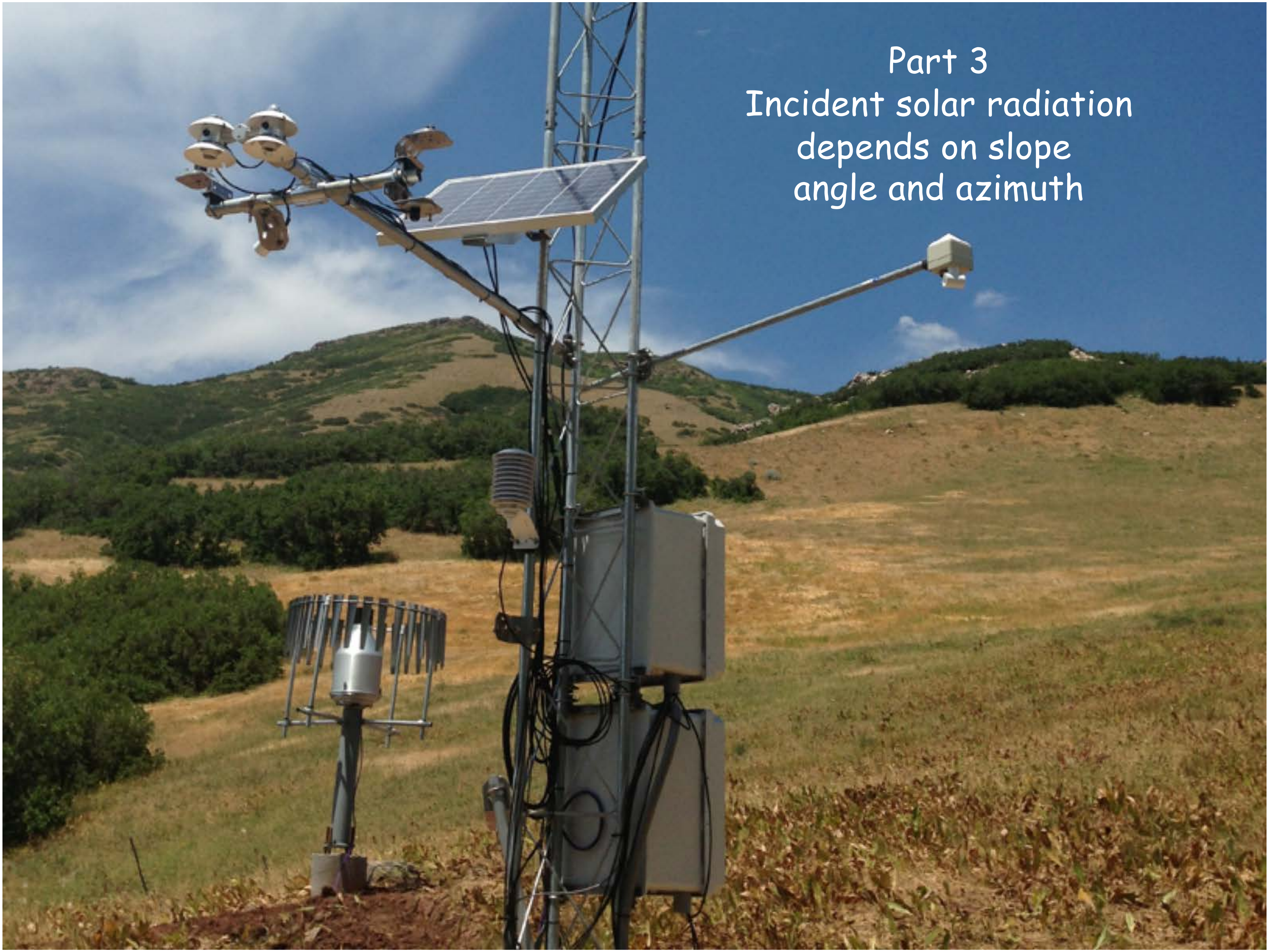
Solar constant:

energy units
1,367 W m^{-2}
(100 - 3,000 nm)

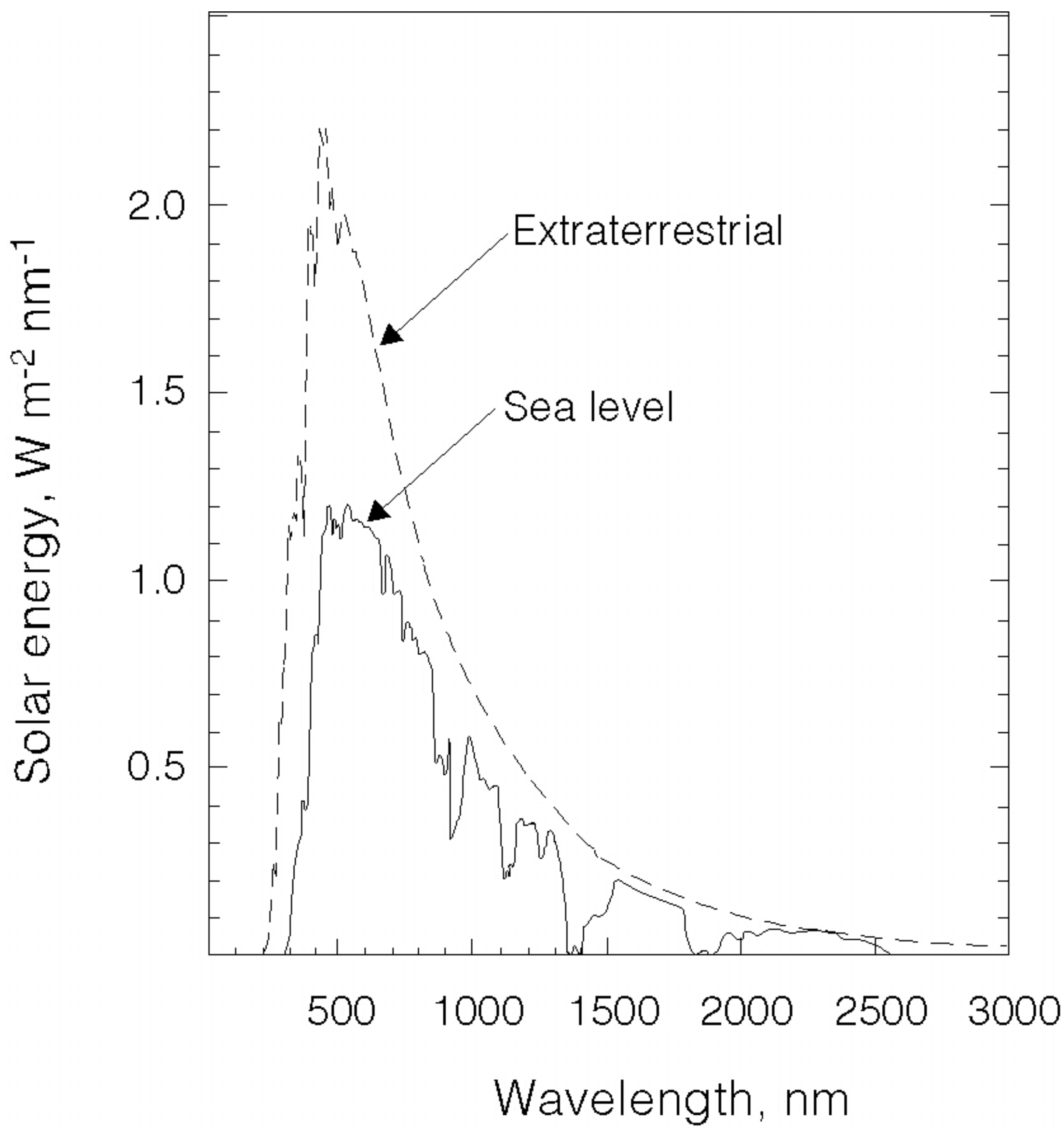
photosynthesis units
2,830 µmol m^{-2} s^{-1}
(400 - 700 nm)

long-wave radiation
(terrestrial objects)

- infrared (4,000 - 11,000 nm)


Part 3
Incident solar radiation
depends on slope
angle and azimuth

Some solar wavelengths are absorbed as photons penetrate the atmosphere



PAR = 400 – 700 nm
photosynthetically active radiation

PPFD =
photosynthetic photon flux density

Sunlight at the Earth’s surface is less than the solar constant because of both atmospheric absorption and atmospheric reflection

- absorption by atmospheric gases
- reflection by atmospheric gases (Rayleigh scattering)
- reflection by large particles and clouds (Mie scattering)

Path length is important – longer path at sunrise/sunset than during the noon hour when the sun is highest in the sky

We calculate the atmospheric influence on sunlight at the Earth's surface

$$I_o = S \cdot \sin(\alpha) \bullet \tau^{1/\sin(\alpha)}$$

Io = direct sunlight on Earth's surface
S = solar constant
α = solar angle above surface
τ = atmospheric transmission coefficient

First we need to calculate the elevation of the sun above the horizon

latitude

declination

$$\sin(\alpha) = \sin(\phi)\sin(\delta) + \cos(\phi)\cos(\delta)\cos(h)$$

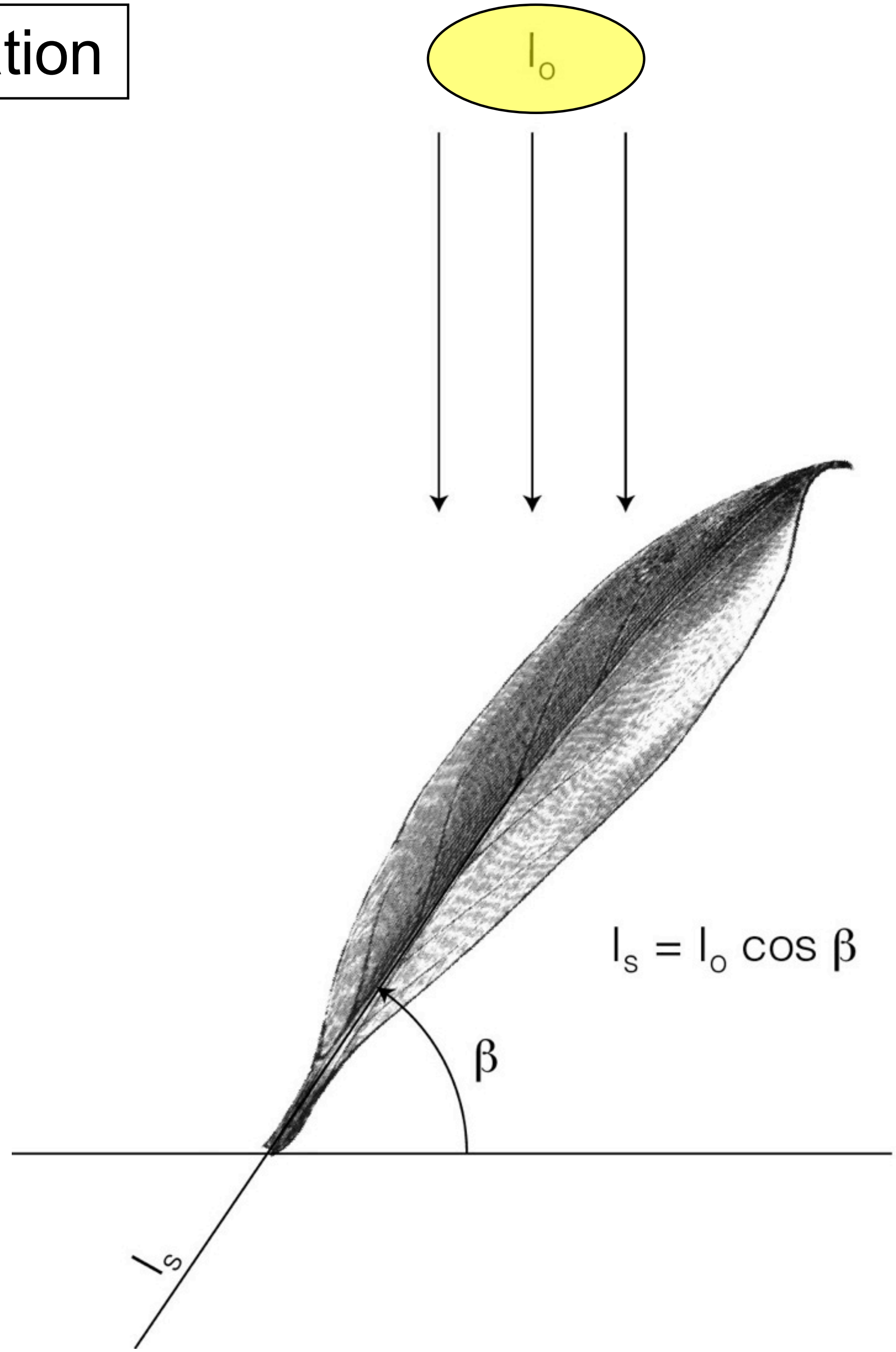
angle of the sun above horizon

hour angle during the day

Cosine Law of Illumination

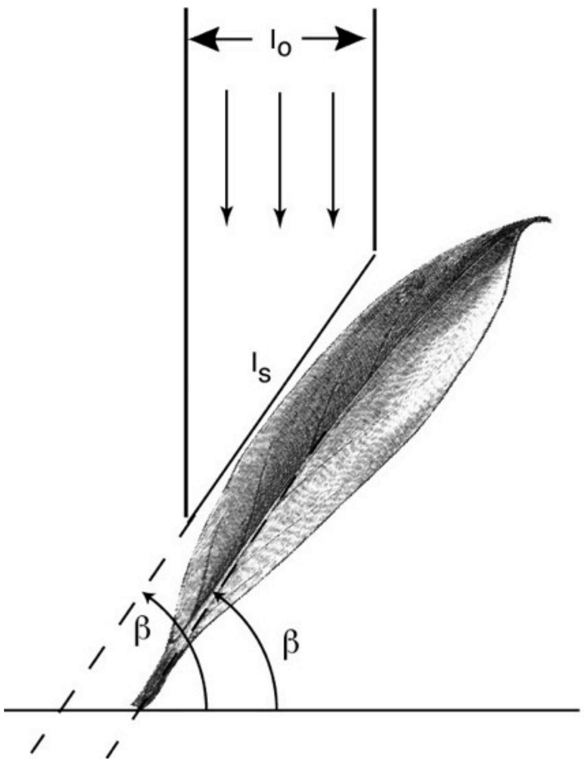
$$I_s = I_o \cos\beta$$

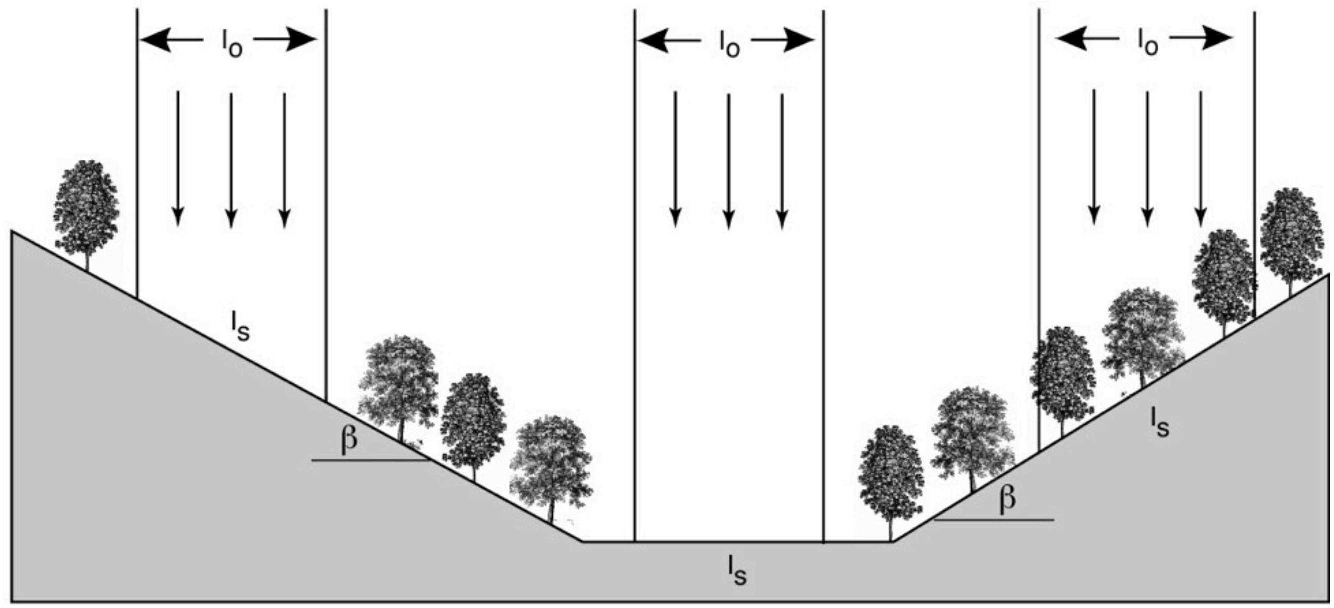
orientation of the object matters !



This same cosine relationship applies to hillsides as well as to leaves

$$I_s = I_o \cos \beta$$





.. since the sun is not often overhead, we need a more complex equation

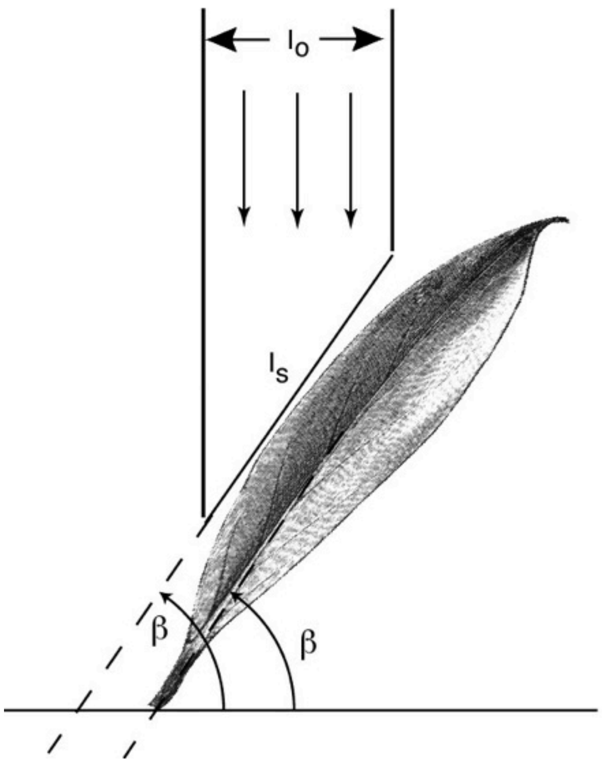
$$\cos(i) = \cos(\beta)\sin(\alpha) + \sin(\beta)\cos(\alpha)\cos(z_{sun} - z_{slope})$$

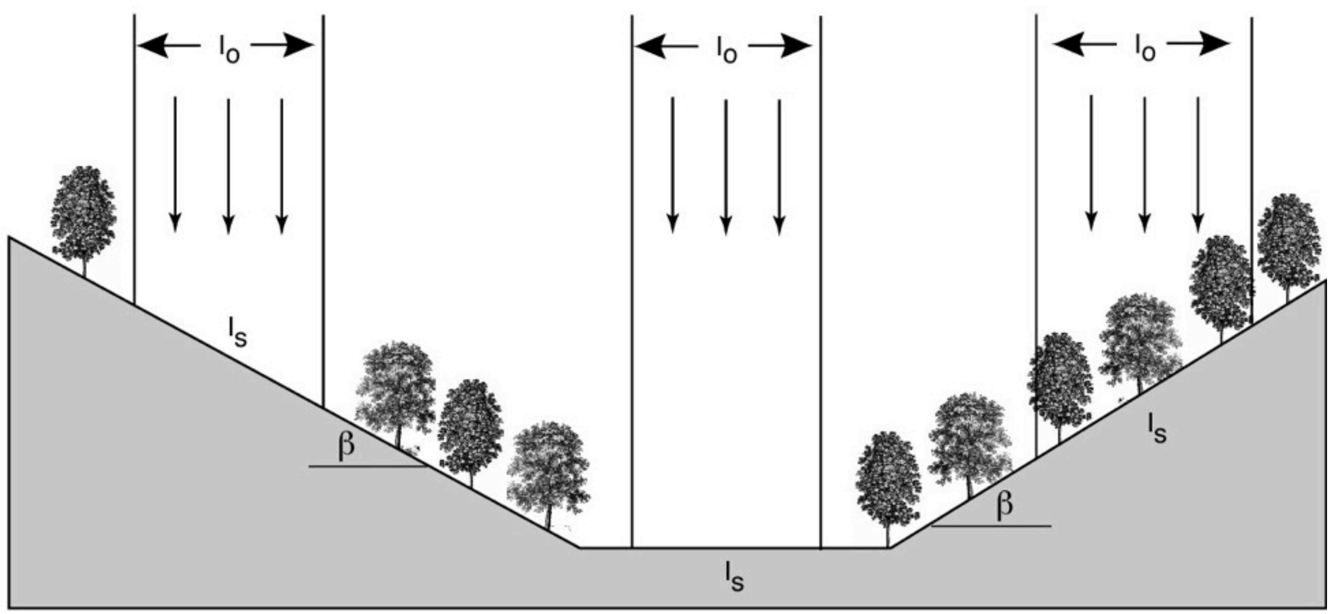
cosine of angle
of incidence

azimuth of the sun and slope;
0° = south
-90° = east
+90° = west
±180° = north

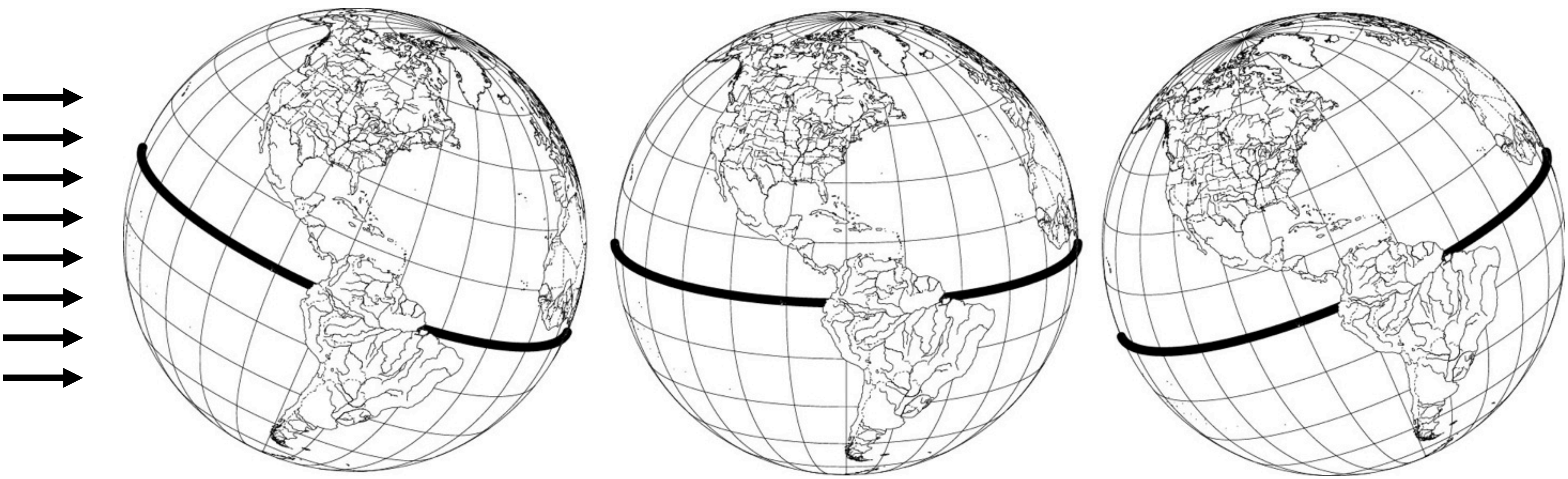
If you are supplied with the flux density of solar radiation measured on a horizontal surface (S_h) (which is how meteorologists report these data), then the flux density incident on a leaf or slope (S_s) will be

$$S_s = S_h \bullet \cos(i)/\sin(\alpha)$$





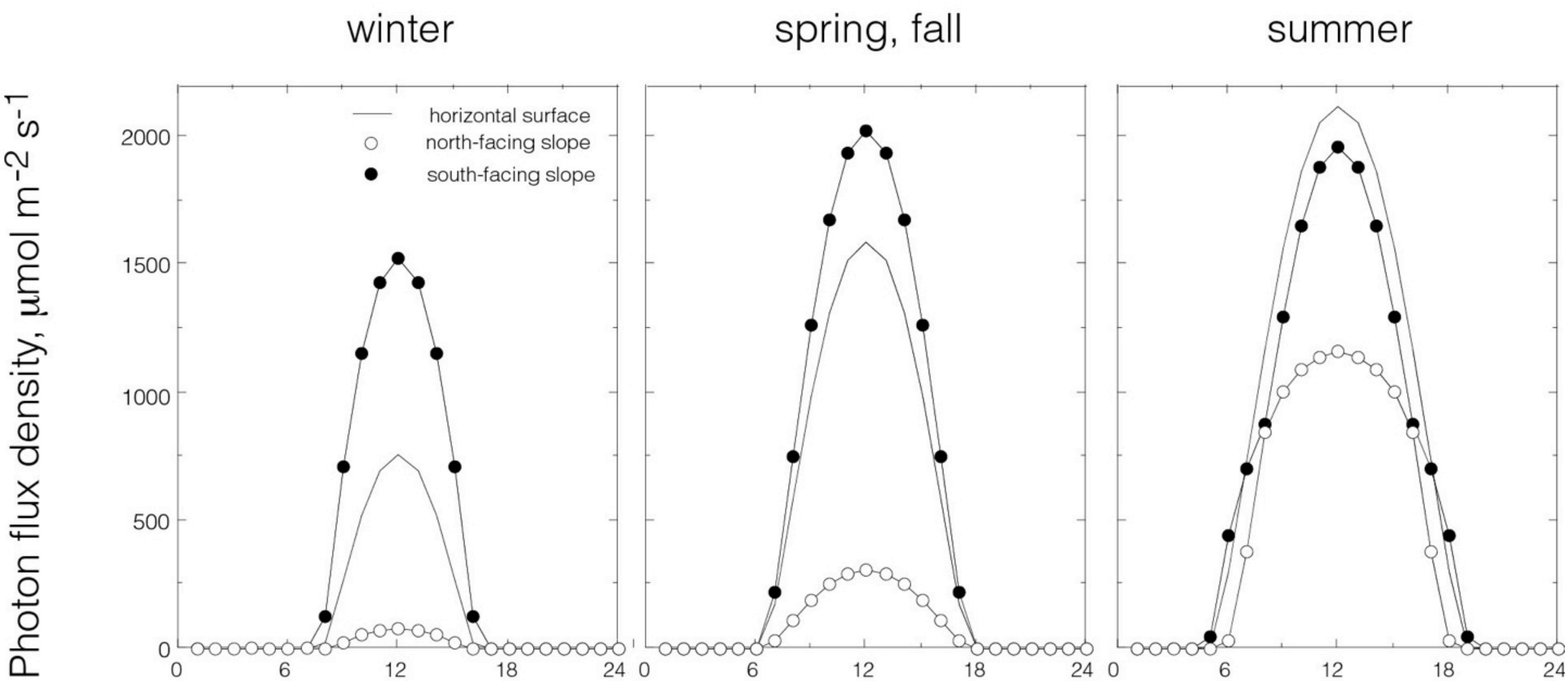
The interplay of surface and declination influence the incident solar radiation levels and energy balance of specific locations



Recall that declination varies from -23.5° to +23.5°

Slope orientation has a significant influence on incident sun light

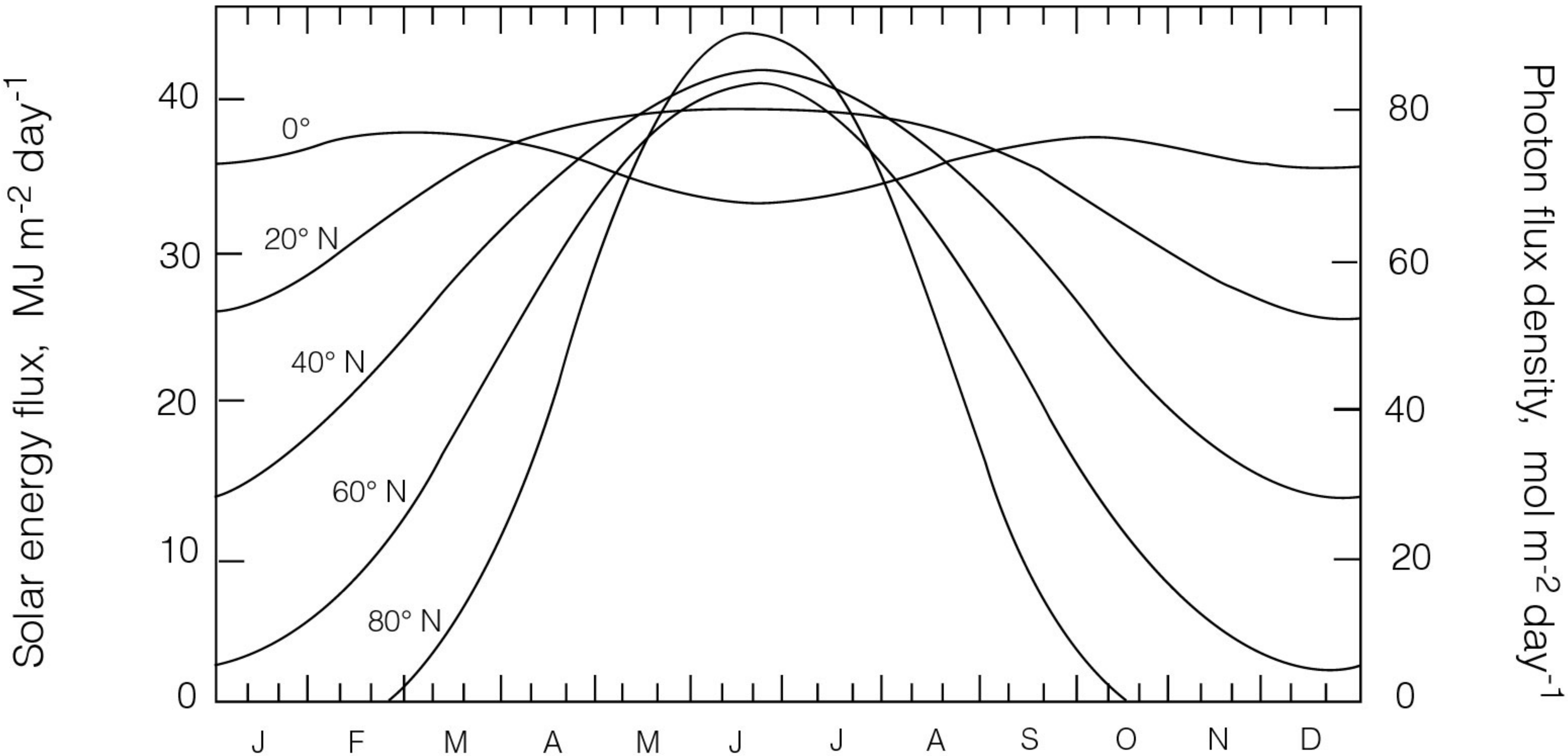
… and many other processes (incl. heating and evaporation)

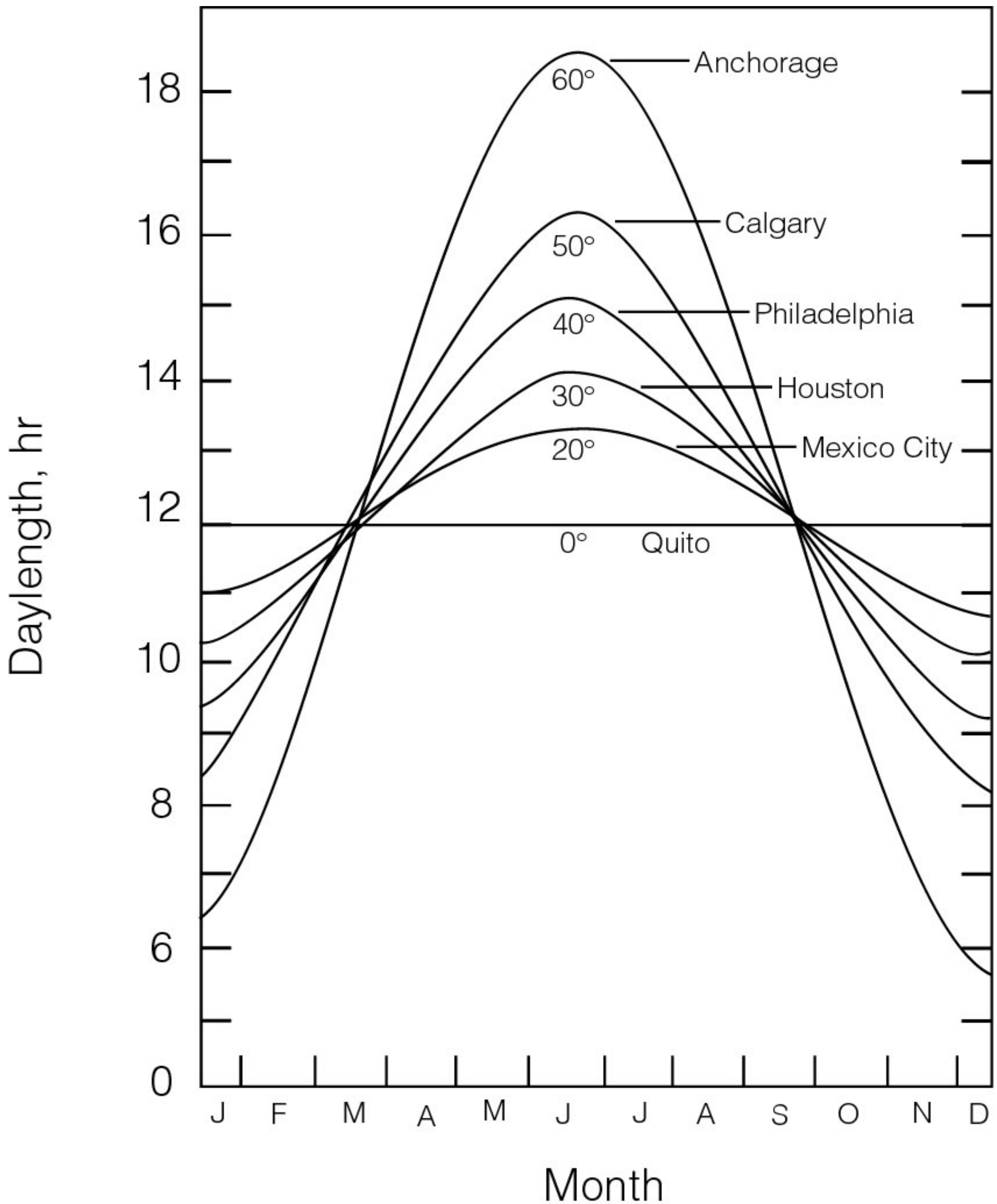


Total daily photons (400-700 nm) in mol m^{-2} day^{-1} received on different slopes in Salt Lake City during different seasons

	winter solstice	equinox	summer solstice
horizontal surface	16.2	43.5	68.9
south facing, 45°	38.4	56.6	61.9
north facing, 45°	0.0	4.9	36.5
east facing, 45°	14.3	36.3	55.1
west facing, 45°	14.3	36.3	55.1

If we integrate the total solar energy flux incident at specific latitudes, we see strong annual patterns and latitudinal differences





Changes in solar declination also influences:

day length - duration of the sun above the horizon

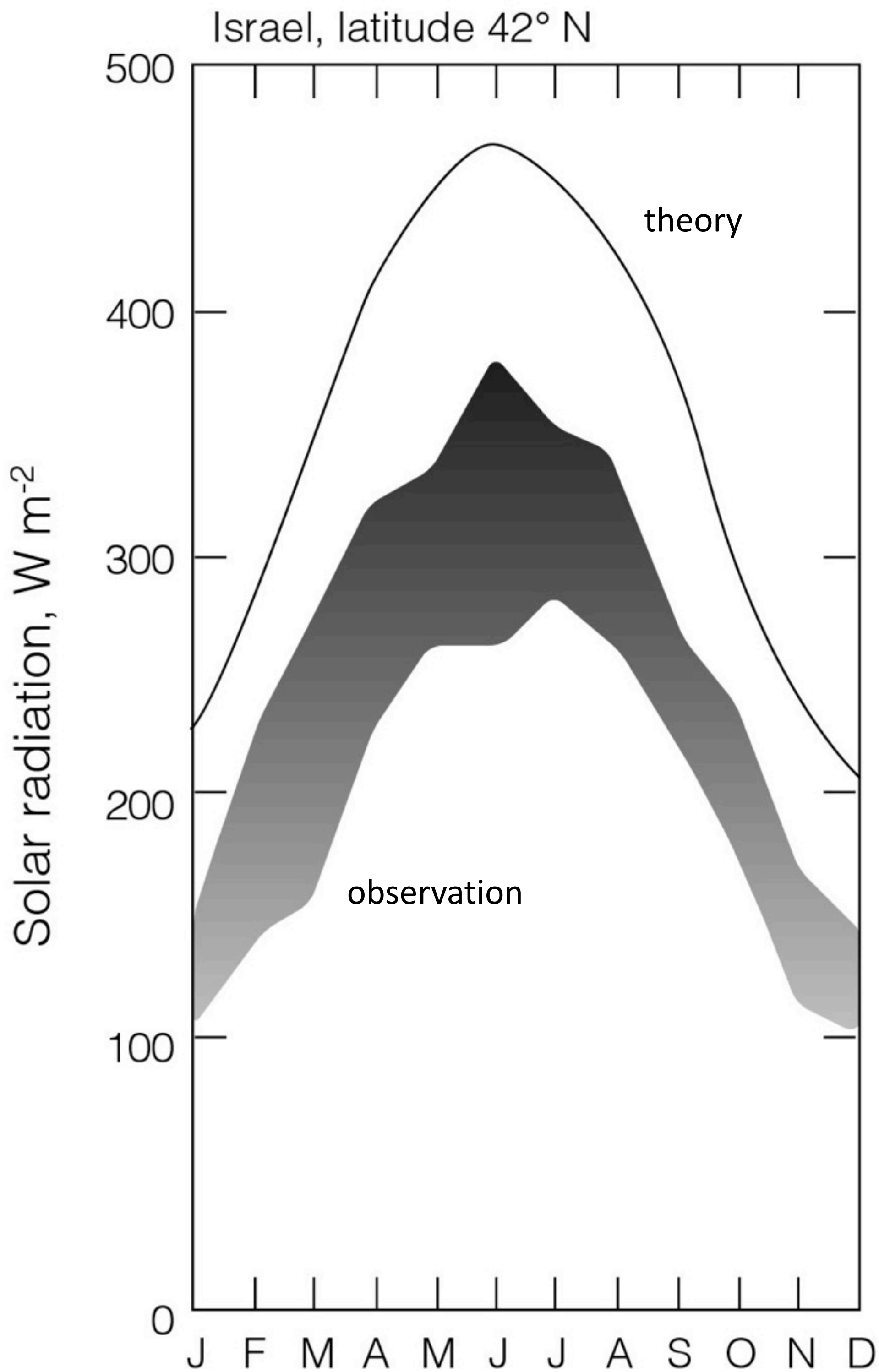
photoperiod - light to dark period in 24 h

Note: only at the equator day length is 12 h

For those interested in the calculation ...

$$\Lambda = 2\cos^{-1}(-\tan(\phi)\tan(\delta))/15$$

day length
in hours



Most regions of the world
experience cloudiness,

reducing the incident sun
light below the theoretical values

… including Israel
which is largely desert

"Compass" plants

Lactuca serriola

Silphinium laciniatum

Notice that some leaf orientations might actually reduce the incident sun light received during the midday period