PBIO-141
Sensory and Physiological Ecology of Plants

4: The Light Environment

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January–February 2022

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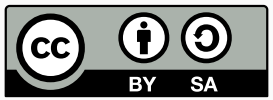


Outline

Solar radiation

Radiation and leaves

Radiation in plant canopies

Radiation climatology

Solar radiation

Radiation: properties

- Wavelength (λ), perceived by humans as 'colours'.
- Direction: one direction ('collimated'), many directions ('diffuse').
  - Direct solar radiation: radiation arriving directly from the sun.
  - Diffuse solar radiation: solar radiation scattered by the atmosphere or reflected by clouds.
  - Global radiation: direct radiation + diffuse radiation.
- Duration: 'length of time' (e.g. day length, or sunfleck frequency).
- Other: polarization, etc.

Radiation: quantities and units

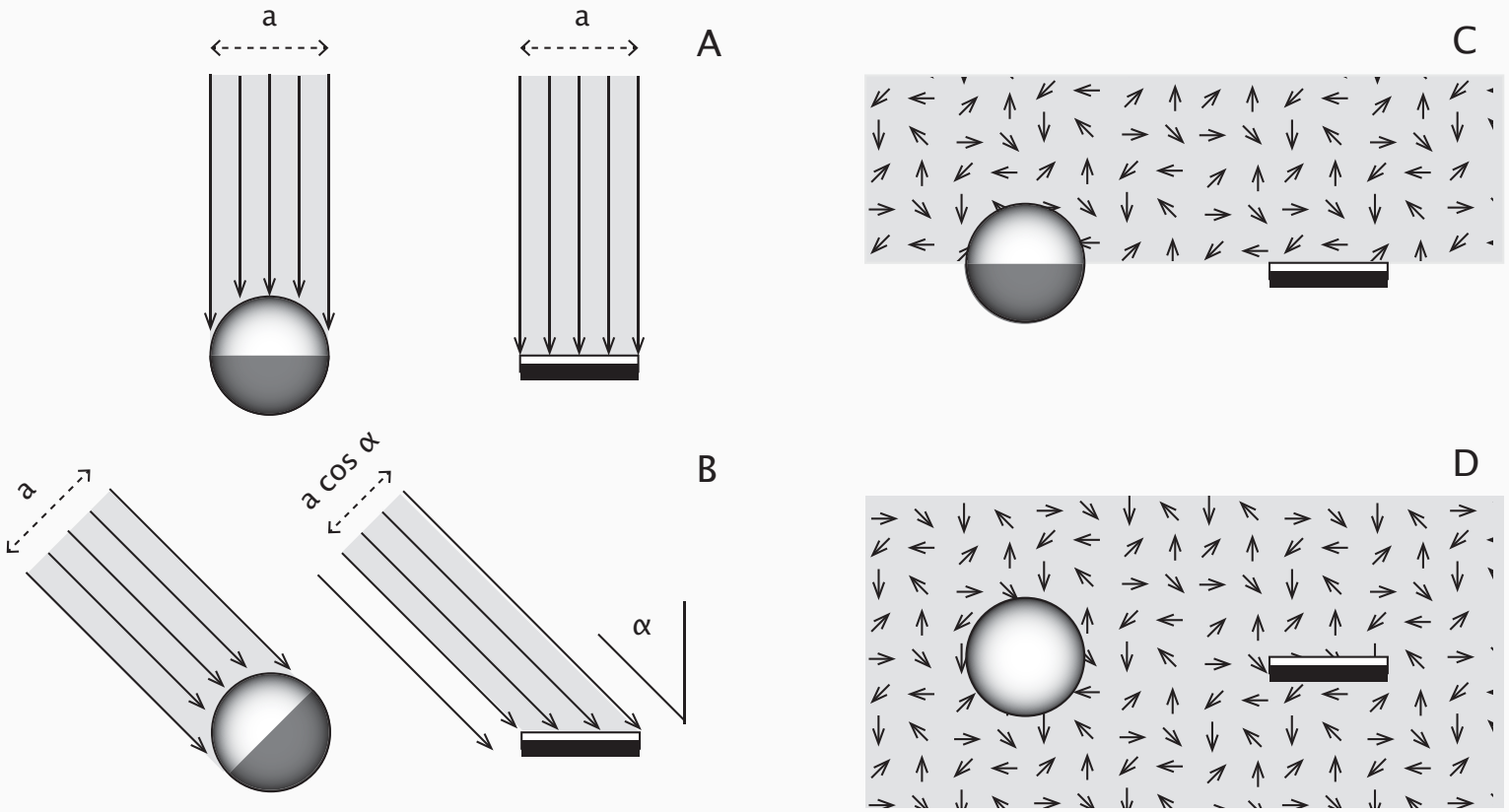
Irradiance: flux of radiation received at a flat surface.

Energy irradiance: irradiance expressed as energy per unit area and unit time. Units: J s^{-1} m^{-2} = W m^{-2}.

Photon irradiance: irradiance expressed as number of photons per unit area and unit time. Units: mol s^{-1} m^{-2}.

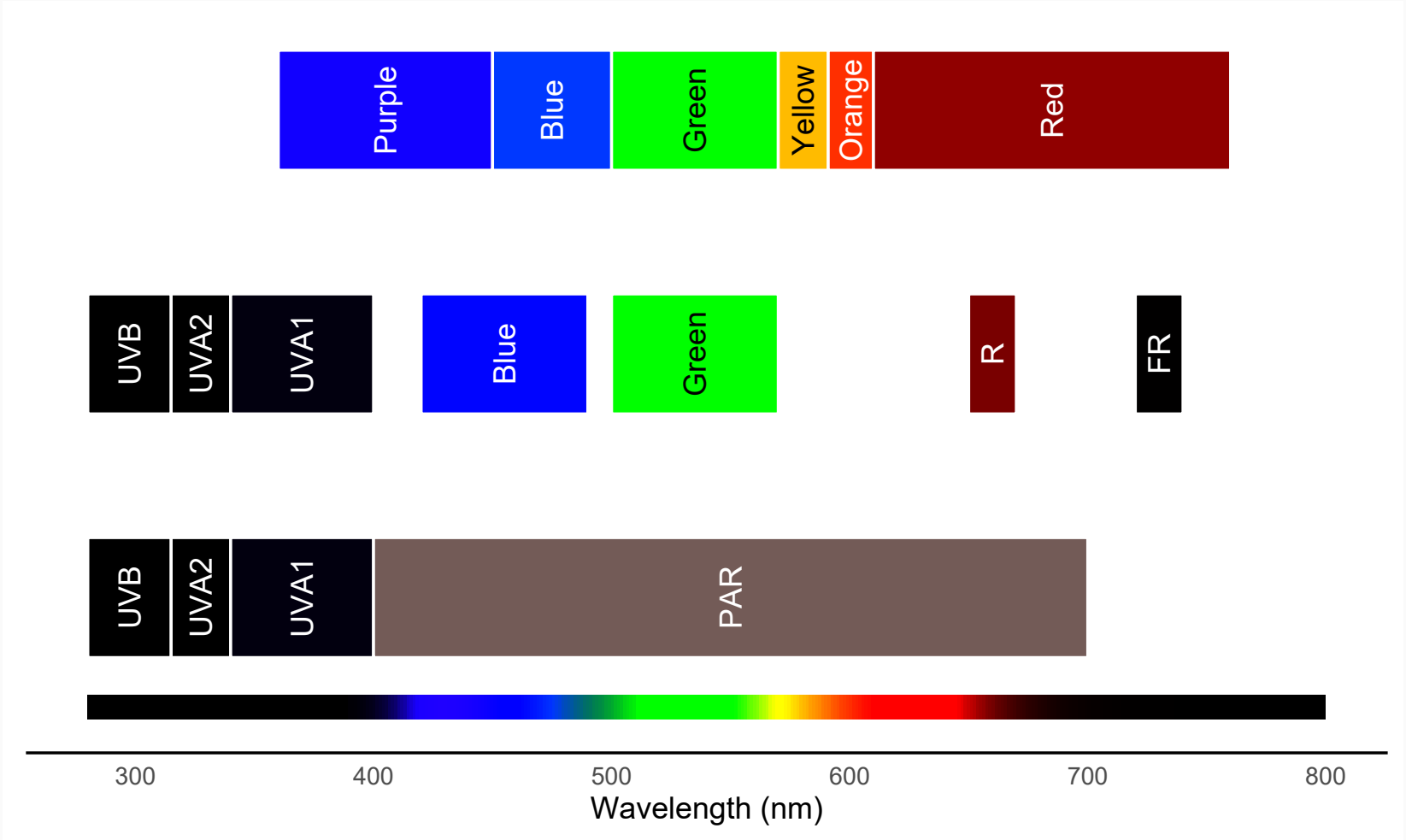
Spectral photon irradiance: Irradiance measured over a narrow band, expressed as number of photons per unit area and unit time and waveband. Units: mol s^{-1} m^{-2} nm^{-1}.

Radiation: Cosine law



Irradiance on a surface depends on the angle of incidence (from Aphalo et al. 2012)

Optical radiation or light colour



Radiation: wavelength ranges of ‘colours’

Shortwave radiation $\lambda < 4\,000$ nm (4 μm).

Longwave radiation $\lambda > 4\,000$ nm (4 μm).

Ultraviolet radiation 100 nm $< \lambda <$ 400 nm.

UV-C 100 nm $< \lambda <$ 280 nm.

UV-B 280 nm $< \lambda <$ 315 nm.

UV-A1 315 nm $< \lambda <$ 340 nm.

UV-A2 340 nm $< \lambda <$ 400 nm.

VIS light, ‘visible to humans’ 380 nm $< \lambda <$ 760 nm.

PAR ‘useful for photosynthesis’ 400 nm $< \lambda <$ 700 nm.

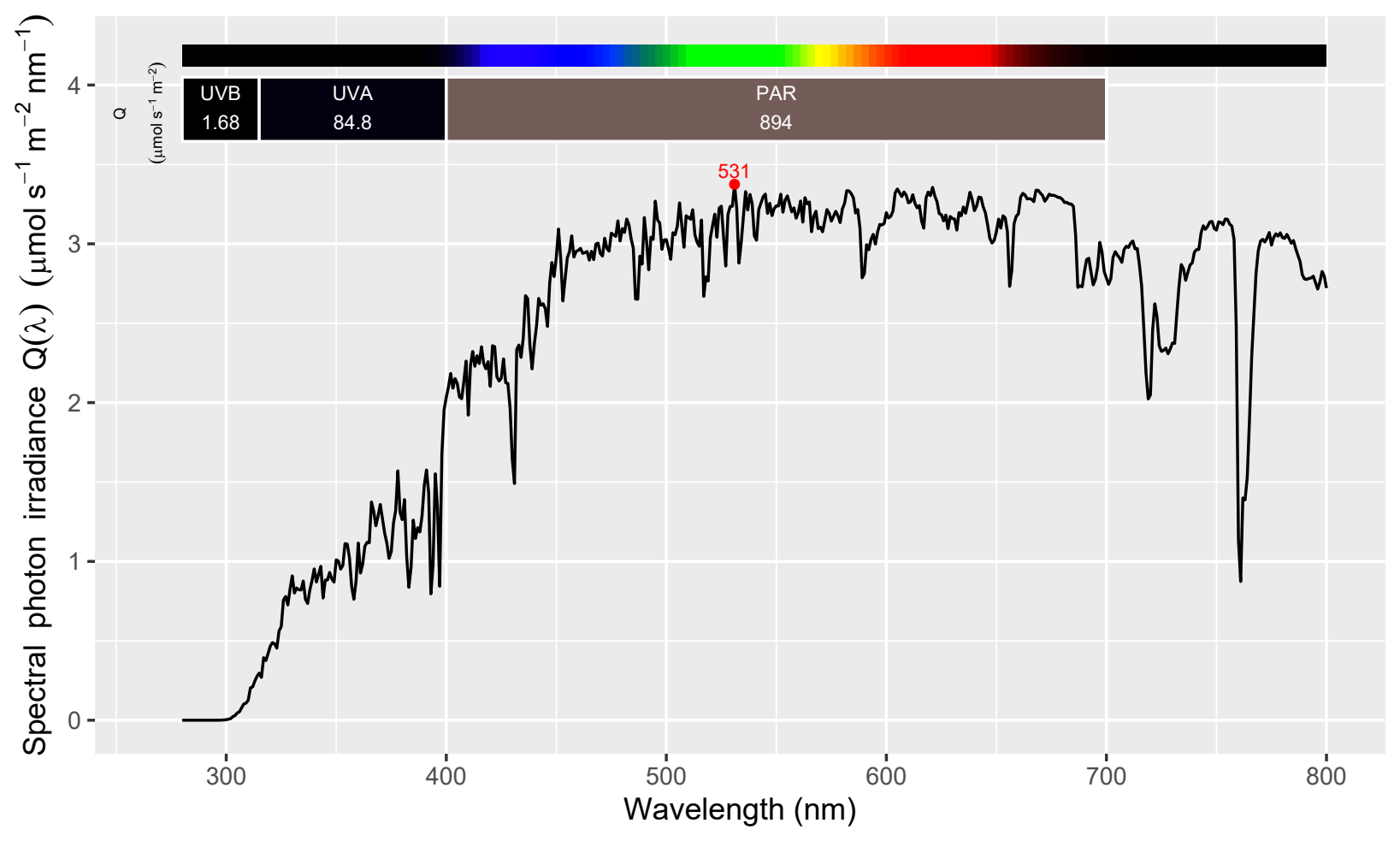
Far red (FR) 700 nm $< \lambda <$ 750–800 nm.

Infrared (IR) ‘thermal’ approx. 750 nm $< \lambda <$ 1 mm.

λ: wavelength.

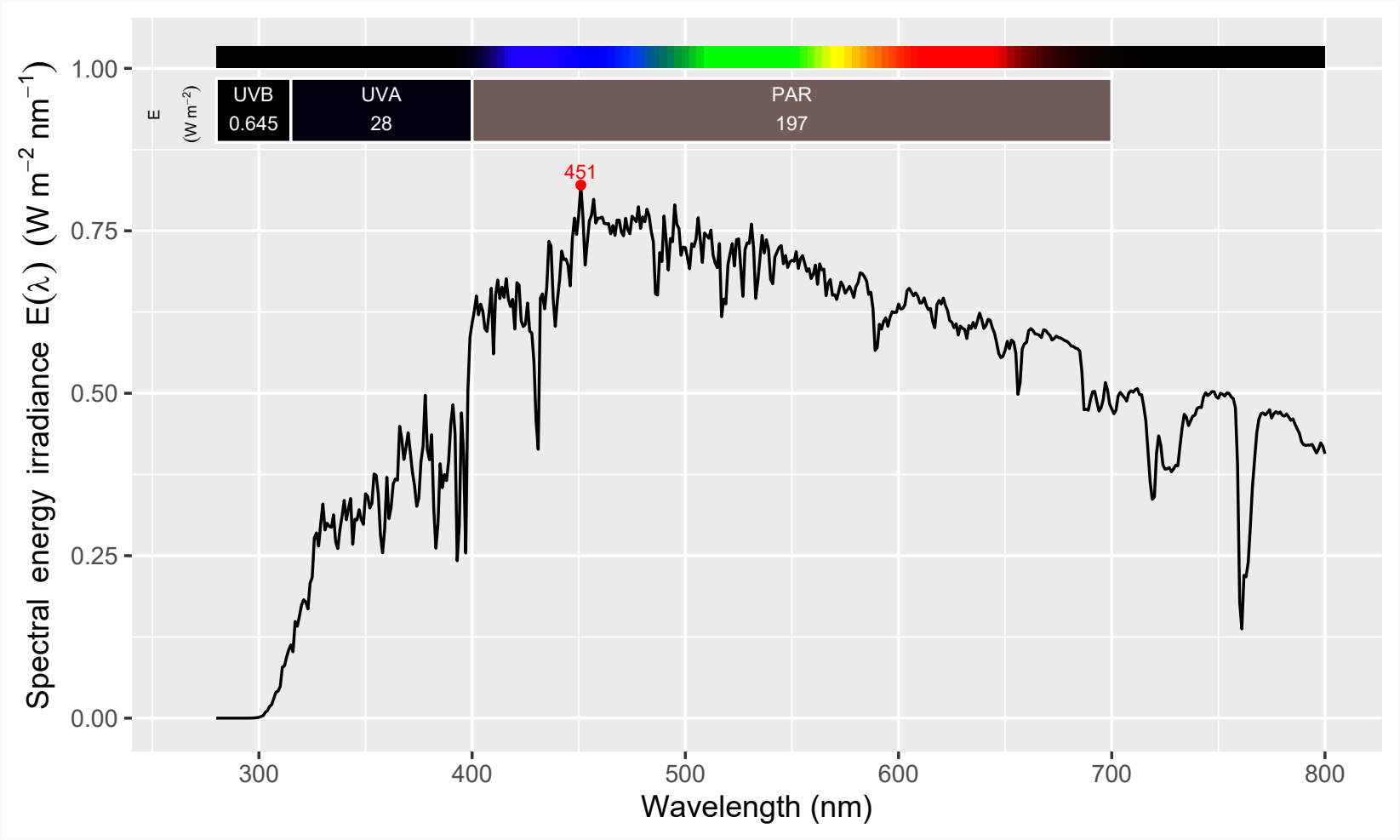
Solar radiation spectrum: photon units

In Viikki, midsummer day, noon, partly cloudy.



Solar radiation spectrum: energy units

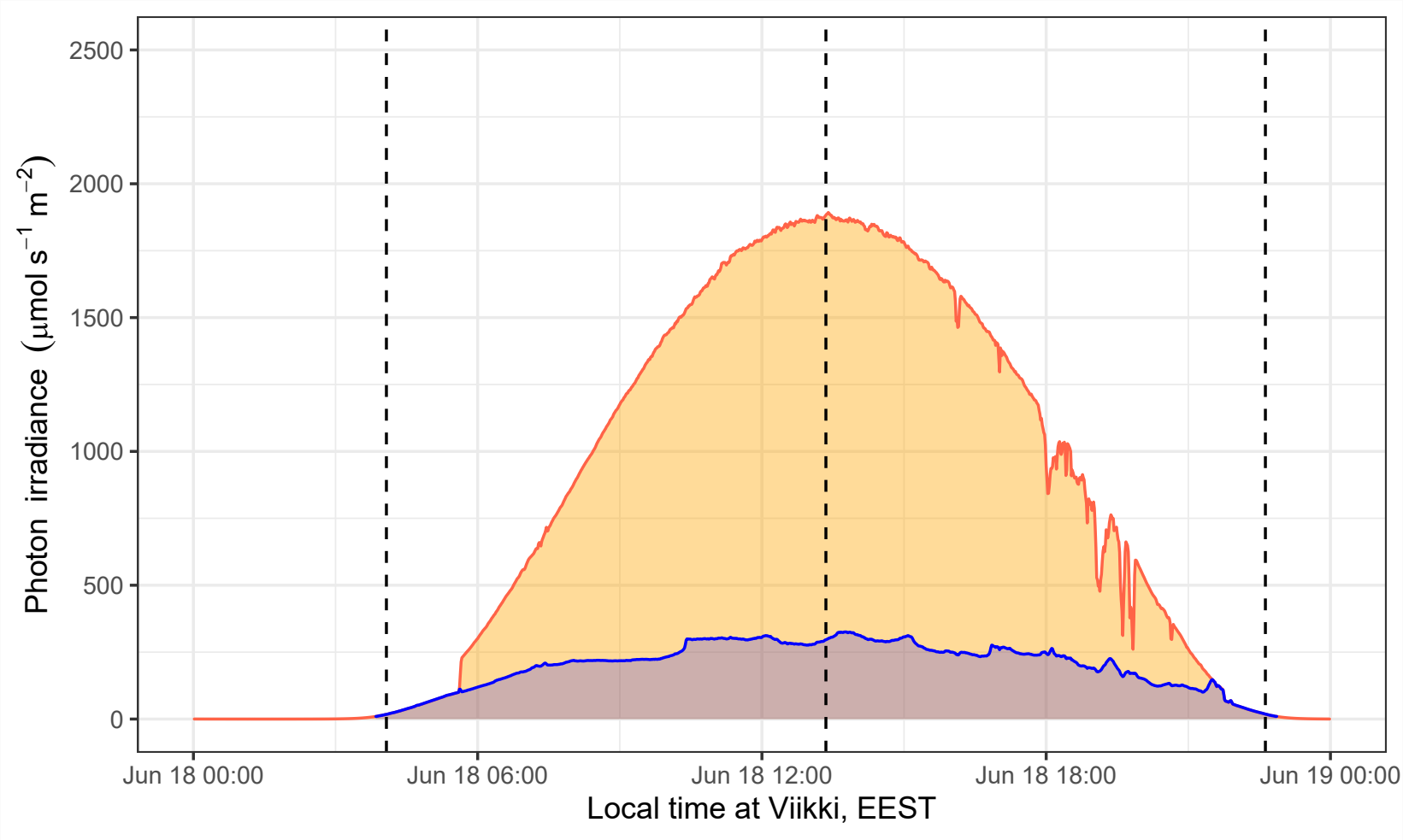
In Viikki, midsummer day, noon, partly cloudy.



Solar radiation (PAR, 400 nm to 700 nm)

In Viikki, one day in summer, almost no clouds.

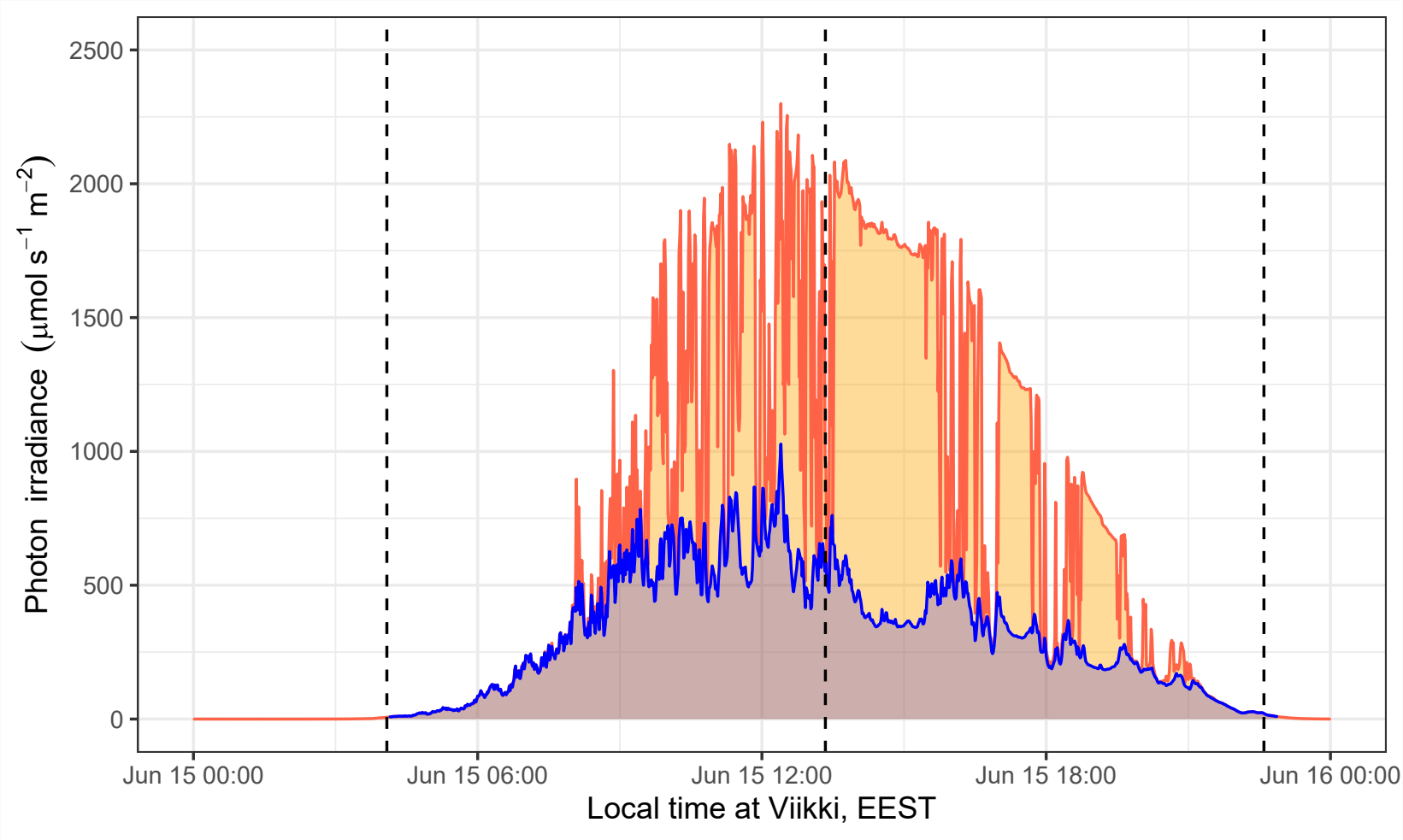
Total PAR (yellow) and diffuse (blue) PAR.



Solar radiation (PAR)

In Viikki, in summer, broken clouds.

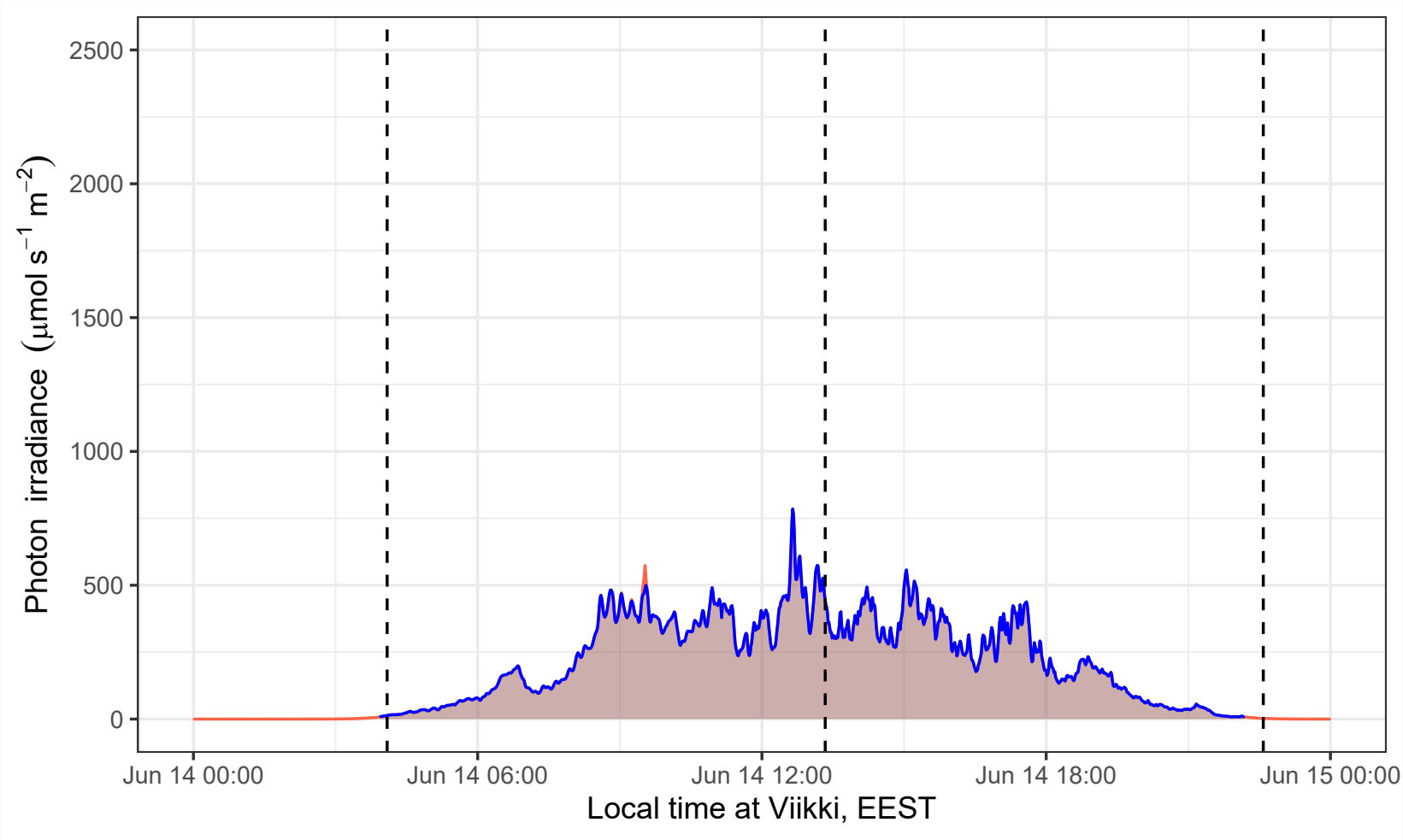
Total PAR (yellow) and diffuse (blue) PAR.



Solar radiation (PAR)

In Viikki, in summer, overcast.

Total PAR (yellow) and diffuse (blue) PAR.



Diffuse sunlight and wavelength: UV and NIR

Light environment

How does it change? 10 min

- Which properties of sunlight change with weather conditions?
- Which properties of sunlight change through a day?
- Which properties of sunlight change with seasons?
- Which properties of sunlight change with latitude?
- Which properties of sunlight change with pollution?
- Do plants modify light properties?
- Which ones?

Radiation and leaves

Light attenuation in leaves

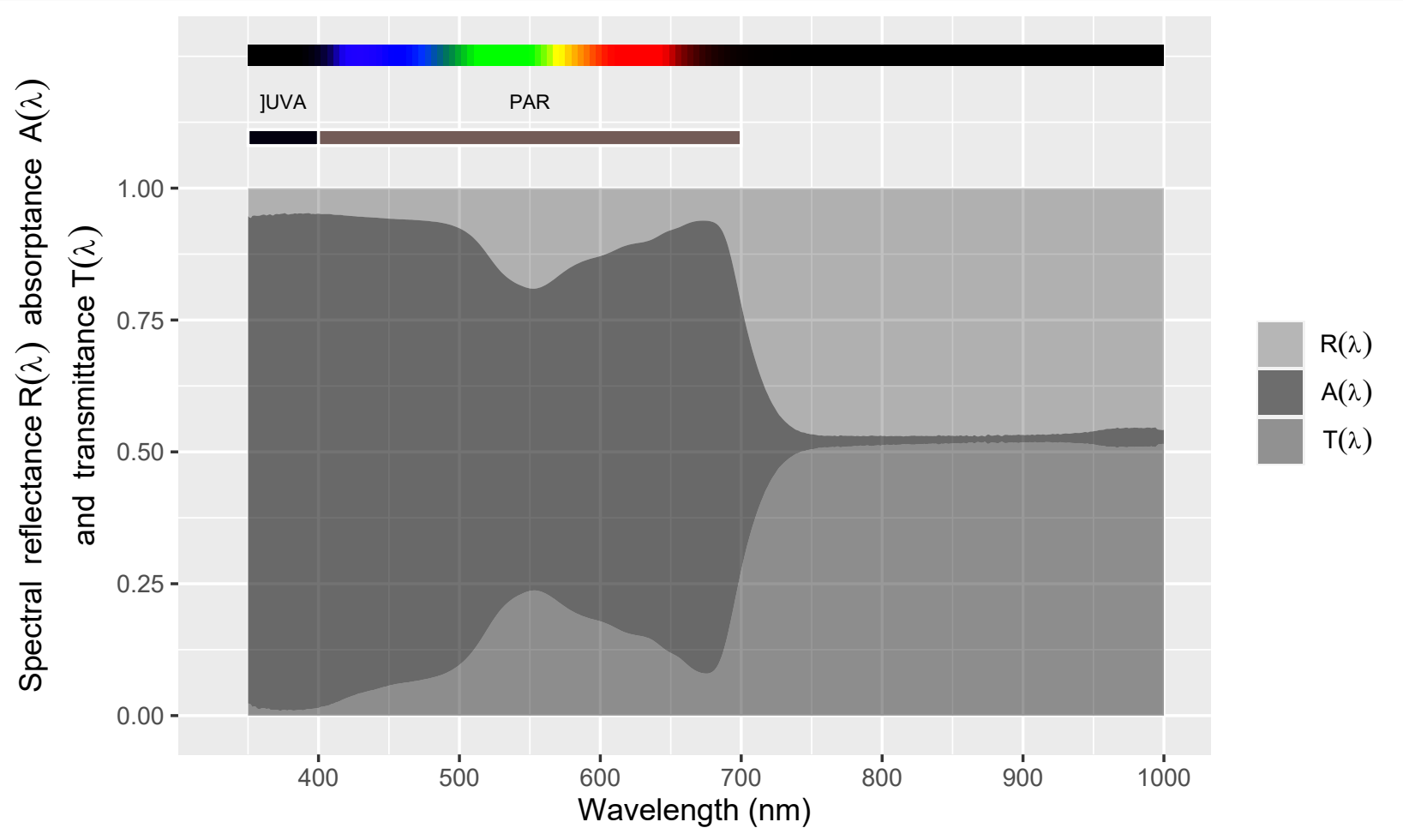
We use the word *attenuation* to mean the process by which irradiance decreases when light travels through any object.

In green leaves, light attenuation depends on:

- chlorophyll concentration,
- cuticle waxes,
- pubescence (trichomes or “hairs”),
- mass pigments like anthocyanins, flavonoids, and other phenolics, and carotenoids,
- angle between the leaf and the direction of radiation.

Transmittance, reflectance and absorptance (quantities)

Solidago from upper canopy, light incident on adaxial (upper) epidermis.



Light and plant leaves

- The absorptance of leaves for light depends on the wavelength.
- In the visible part of the spectrum they reflect and transmit more green light than other colours of light.
- A little further towards longer wavelengths, they reflect and transmit most of the radiation.
- Later in the course we will see how plants perceive this ratio through photoreceptors called phytochromes.

Looking at reflected far-red radiation

Flower patterns in ultraviolet-A

Radiation in plant canopies

Light in plant canopies

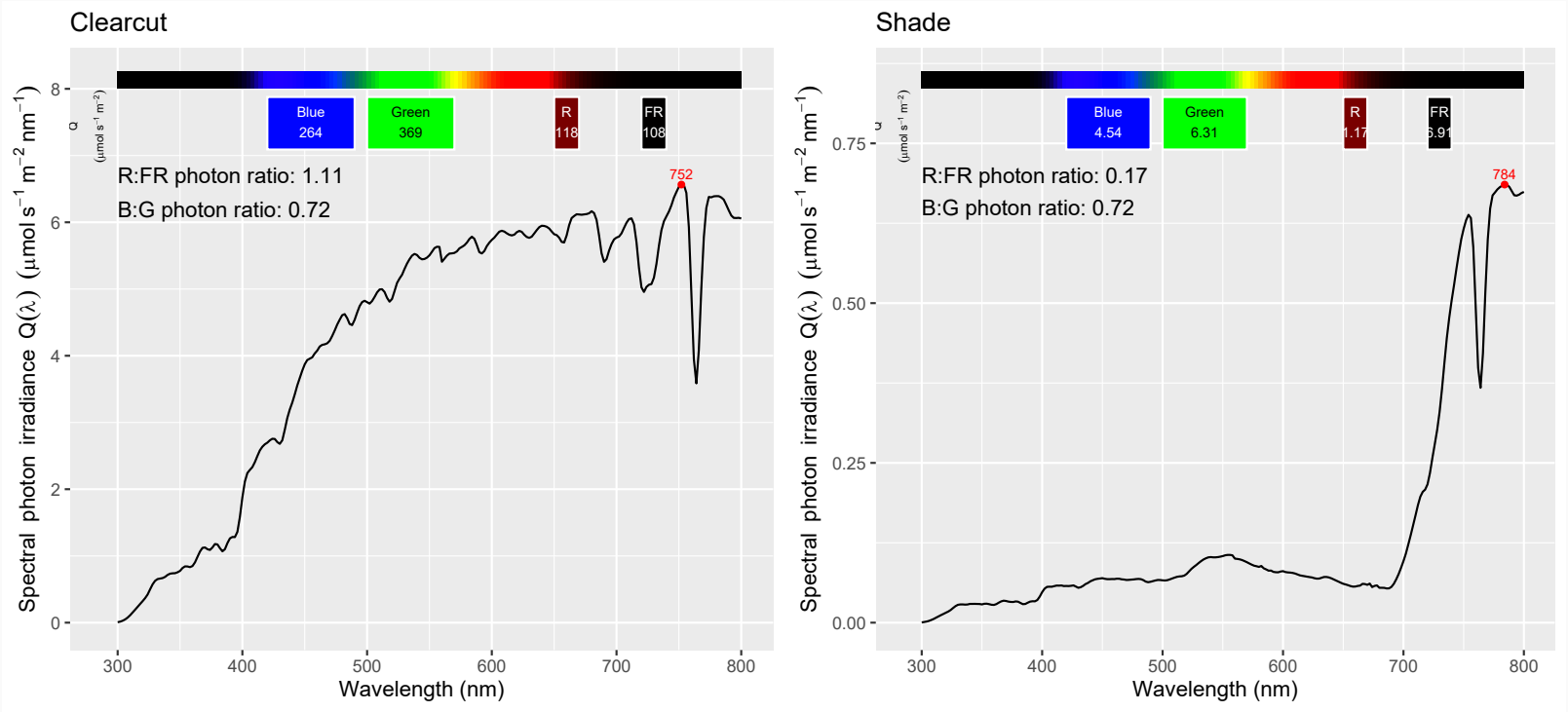
We use the word *attenuation* to mean the decrease in irradiance that occurs when light travels through any object.

In the case of canopies, light attenuation depends on:

- area of foliage,
- grouping of the leaves,
- angle between leaves and the direction of radiation.

Solar radiation: shade

Lammi, 2006-06-29, Norway spruce shade vs. nearby clearcut.



Light in plant canopies

- LAI = $\frac{\text{leaf area}}{\text{ground area}}$
- LAI: leaf area index.
- Leaf area refers to the sum of the projected area of all the leaves. (Projected area for flat leaves means area of one side.)
- Empirical indexes can be used to describe clumping.
- (A clump is a thick group or bunch. Leaves grouped like for example on pines.)

Light in plant canopies

- Borrowed from chemistry…
  we use the Lambert-Beer extinction law…
  replacing concentration of solute by “concentration” of leaves, measured as LAI.
- the equation as modified by Monsi and Saeki is:

$$I_z = I_0 \, \mathrm{e}^{-k \, \mathrm{LAI}},$$

  where k is the extinction coefficient, I_0 is the irradiance above the canopy, and I_z the irradiance below the canopy.

Light in plant canopies

How can a plant adjust k so as maximize energy capture? (light as resource)
What signals could it use as a source of information?
What would be an example of adaptation?
What would be an example of acclimation?

Maize field

Maize field in the Pampas, Argentina.

Pine forest

Scots pine forest in Joensuu.

Forest canopy

Looking upwards, circular ‘fish-eye’ objective (180°). May 15 and June 6 in Viikki.

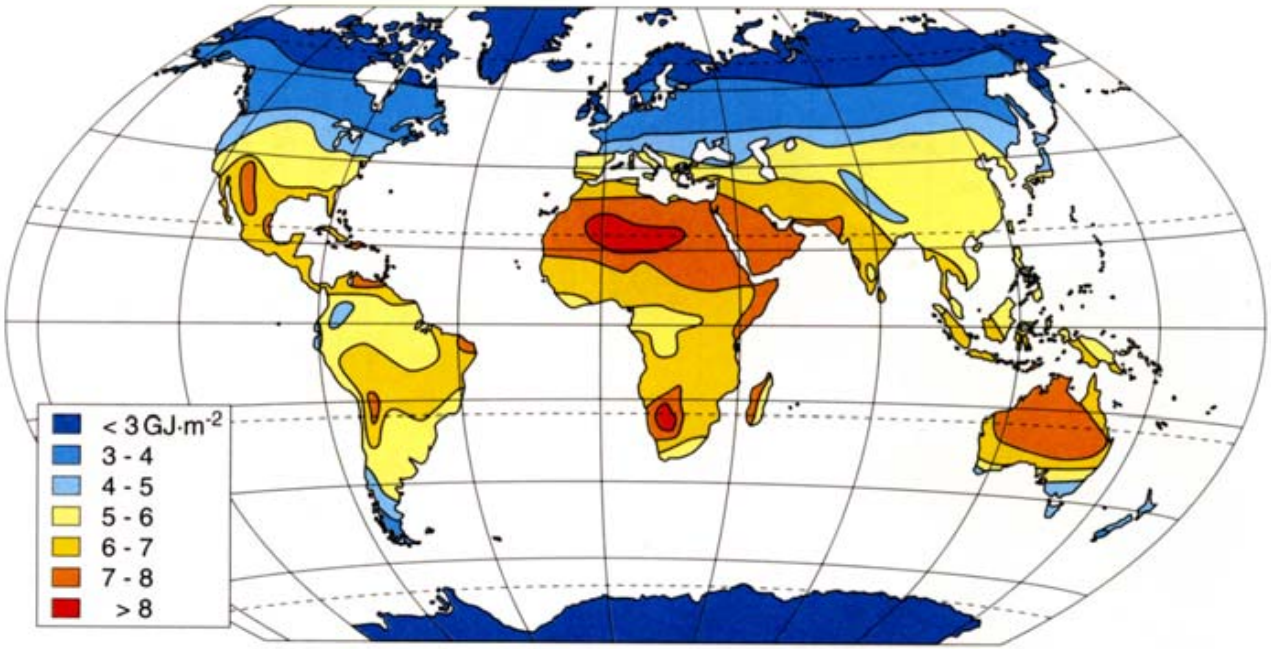
Photos: T. M. Robson and S. Hartikainen.

Radiation climatology

Solar radiation as a resource

- Solar radiation is the source of energy for photosynthesis, but only absorbed light can be used.
- The yearly total of radiation depends on latitude and cloudiness.
- Arid regions tend to receive more sunlight, but there is little vegetation to use it because of lack of water.

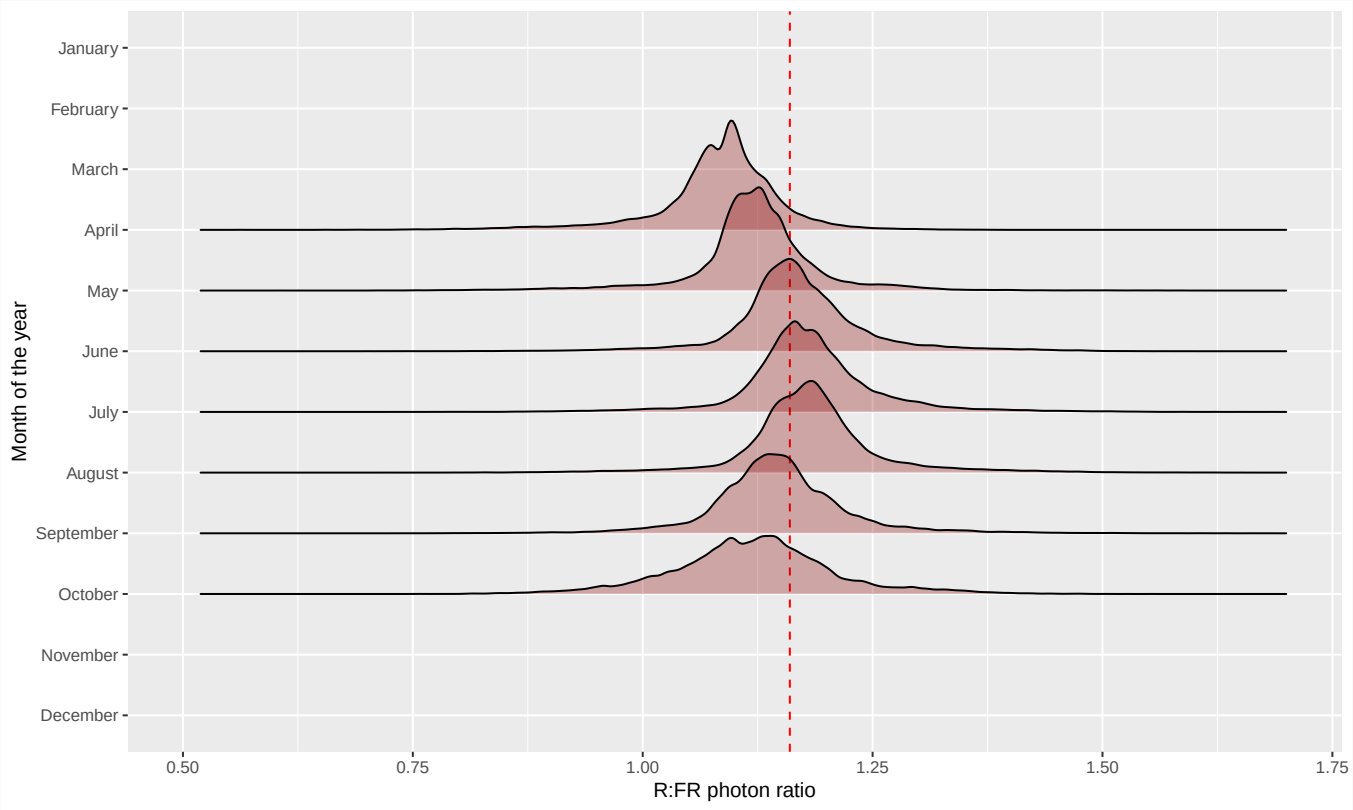
Solar radiation as a resource



Color chart Ia (cf. page 33): Annual totals of global radiation (GJ m^{-2}). Local differences are mainly due to different latitudes and regionally varying cloud covers. (Adapted from maps in Uchijima and Seino 1987; Kotlyakov et al. 1998)

(From Larcher 2003).

R:FR photon ratio (sunlight, no shade)



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