Schedule

08/31/17 (Lecture #1)
09/05/17 (Lecture #2)
09/07/17 (Lecture #3)
09/12/17 (4:00 – 18:30 h) (Lecture #4-5)
09/14/17 (Lecture #6): radiation
09/21/17 (Lecture #7): radiation lab
09/26/17 (4:00 – 18:30 h) (Lecture #8-9)
09/28/17 (Lecture #10)
10/03/17 (12:00 – 8:00 h) (Lab #1)
10/10/17 (12:00 – 8:00 h) (Lab #2)
10/20/17 (8:00 -17:00 h) (Lab #3)
10/24/17 (Q&A #1)
10/26/17 (Lecture #11)
11/07/17 (Q&A #2)
11/14/17 (Q&A #3)
11/21/17 (Q&A #4)
12/07/17 (Lecture #12): Term paper due on Dec. 14, 2017

- 12 lectures
- 3 long labs (8 hours each)
- 2-3 homework
- 1 group project
- 4 Q&A (Geography Room 206)
- Dr. Dave Reed on CRBasics with CR5000 datalogger

Radiation (Ch 10 & 11; Campbell & Norman 1998)

- R_t, R_l, R_n, R_{in}, R_{out}, PAR, *albedo*, turbidity
- Greenhouse effect, Lambert's Cosine Law
- Sensors: Pyranometer, K&Z CNR4, Q7, PAR, etc.
- Demonstration of solar positions
- Programming with LogerNet

Review of Radiation

Solar constant: 1.34-1.36 kW.m^{-2}, with about 2% fluctuations

Sun spots: in pairs, ~11 yrs frequency, and from a few days to several months duration

Little ice age (1645-1715)

Greenhouse effects (atmosphere as a selective filter)

Low absorptivity between 8-13 μm

Clouds

Elevated CO_2

Destroy of O_3

O_3 also absorb UV and X-ray

Global radiation budget

Related terms: cloudiness turbidity (visibility), and *albedo*

Lambert's Cosine Law

Other Considerations

Zenith distance (angle)

Other terms

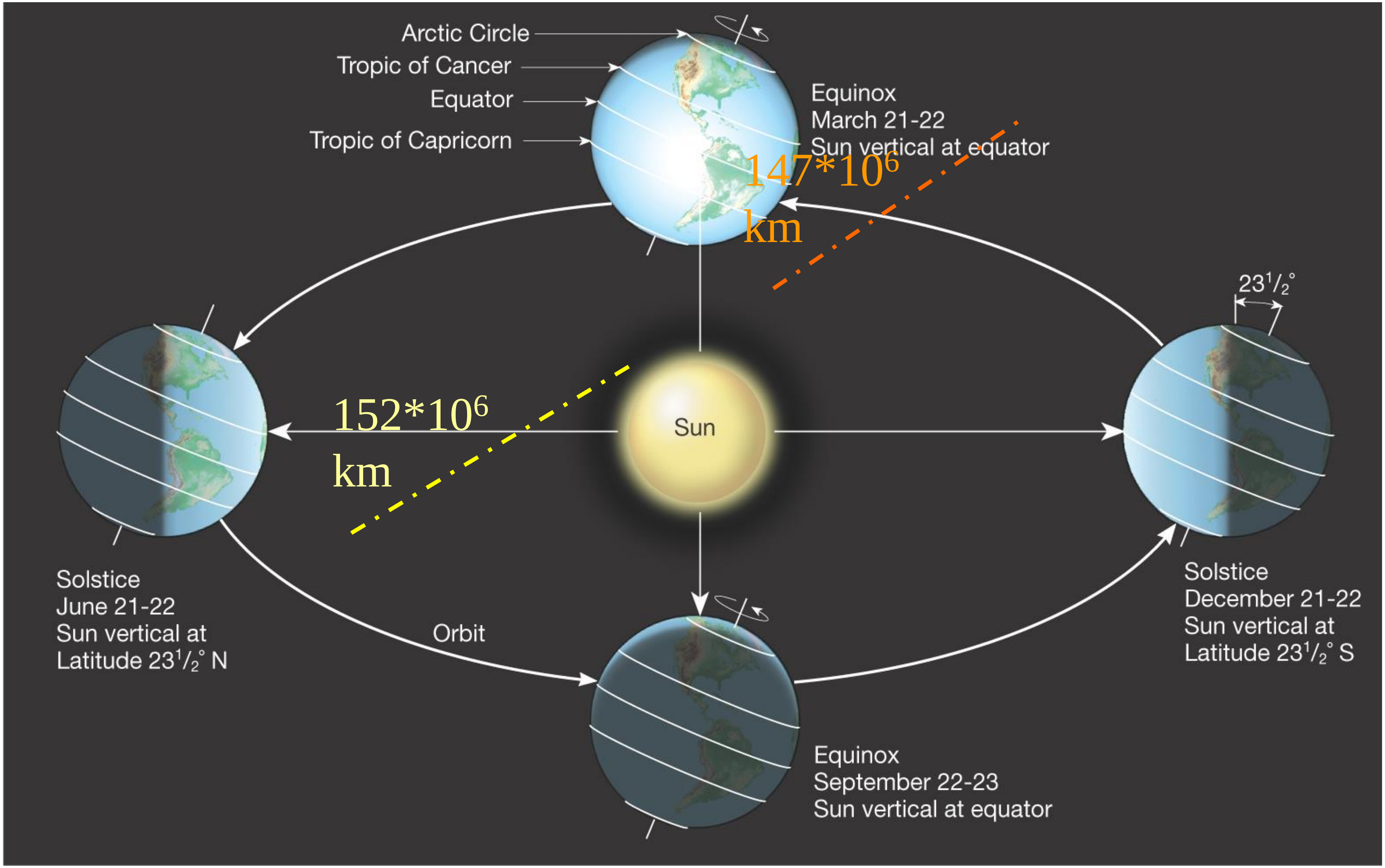
Solar noon: over the meridian of observation

Equinox: the sun passes directly over the equator

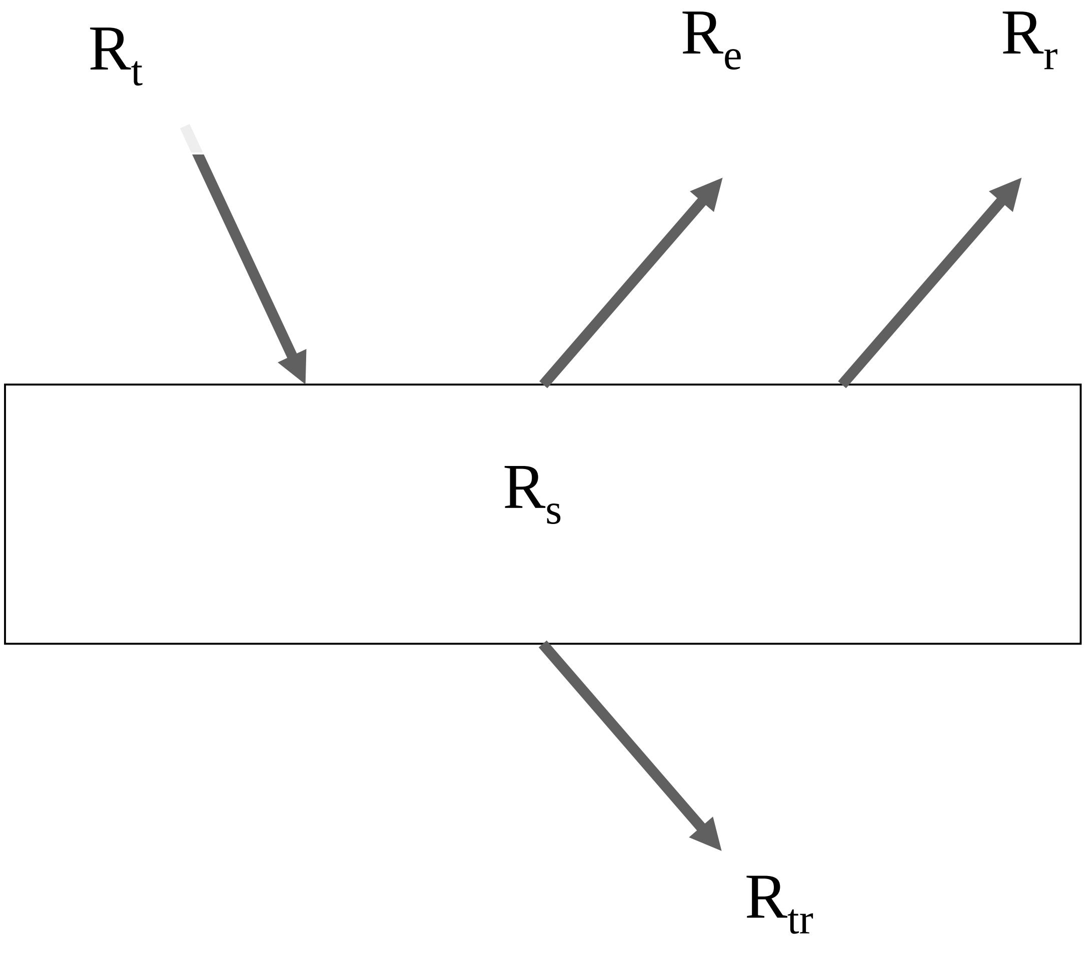
Solstice

Solar declination

Path of the Earth around the sun



Radiation Balance Model



Solar declination (D): an angular distance north (+) or south (-) of the celestial equator of place of the earth's equator.

Solar elevation angle (β): the angular distance from the meridian of the observer (90-θ).

Azimuthal angle: the angle between the true north and the projection of sun's rays onto the horizon.

Turbidity: any condition of the atmosphere which reduced its transparency to radiation, especially to visible radiation.

Albedo: reflection of solar beams (all wavelengths, or just shortwave)

Radiation

$$\mathbf{e = h \cdot c / \lambda}$$

Planck's equation

e - energy of photon

h - Planck's constant

c - speed of light

λ - wavelength of radiation

ν - frequency of radiation

$$\lambda \cdot \nu = c \rightarrow e = h \cdot \nu$$

Blackbody radiation

- Perfect absorber & emitter
- Blackbody absorber in certain wavelength
- SNOW

  poor absorber in 400-700 nm

  black body absorber >5 μm

Stefan-Boltzmann Law

$E = e * \sigma * T^4$

where e is emmisivity (0-1). Blackbody has e of 1

σ is Stefan-Boltzmann's constant (56.697×10^{-9} W m^{-2} K^{-4})

Spectral distribution of blackbody radiation

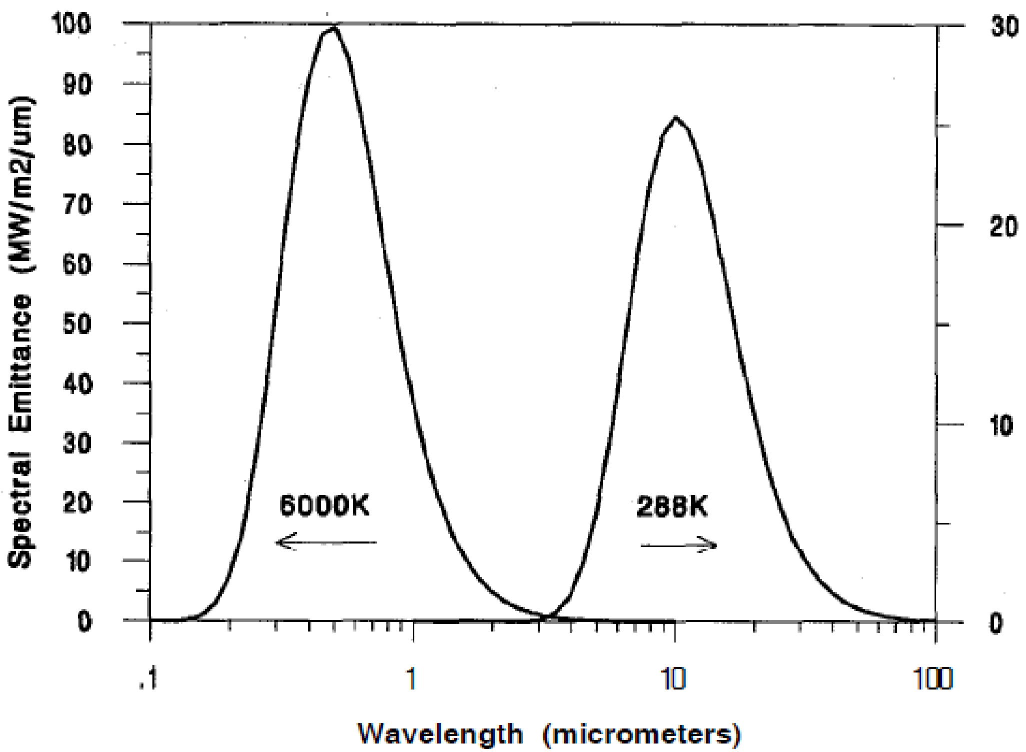


FIGURE 10.4. Emittance spectra for 6000 K and 288 K blackbody sources approximating emission from the sun and the earth.

$$\lambda_m = 2897 \cdot T^{-1}$$

Spectral distribution of solar radiation

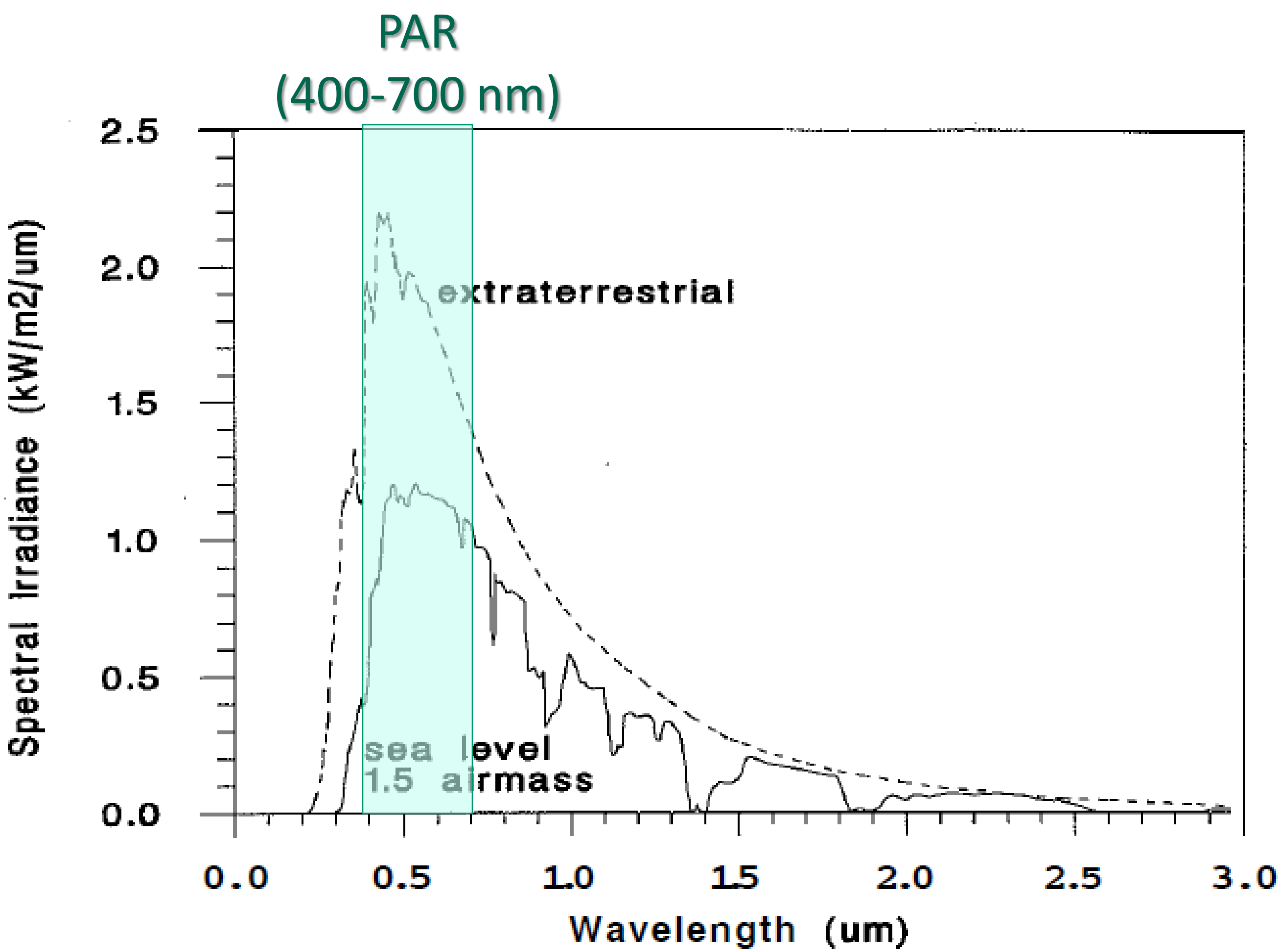


FIGURE 10.5. Spectral irradiance of the sun just outside the atmosphere and at sea level through a 1.5 airmass atmospheric path. Atmospheric absorption at short wavelengths is mainly from ozone. At long wavelengths it is mainly from water vapor (redrawn from Gates, 1980).

Spectral distribution of earth radiation

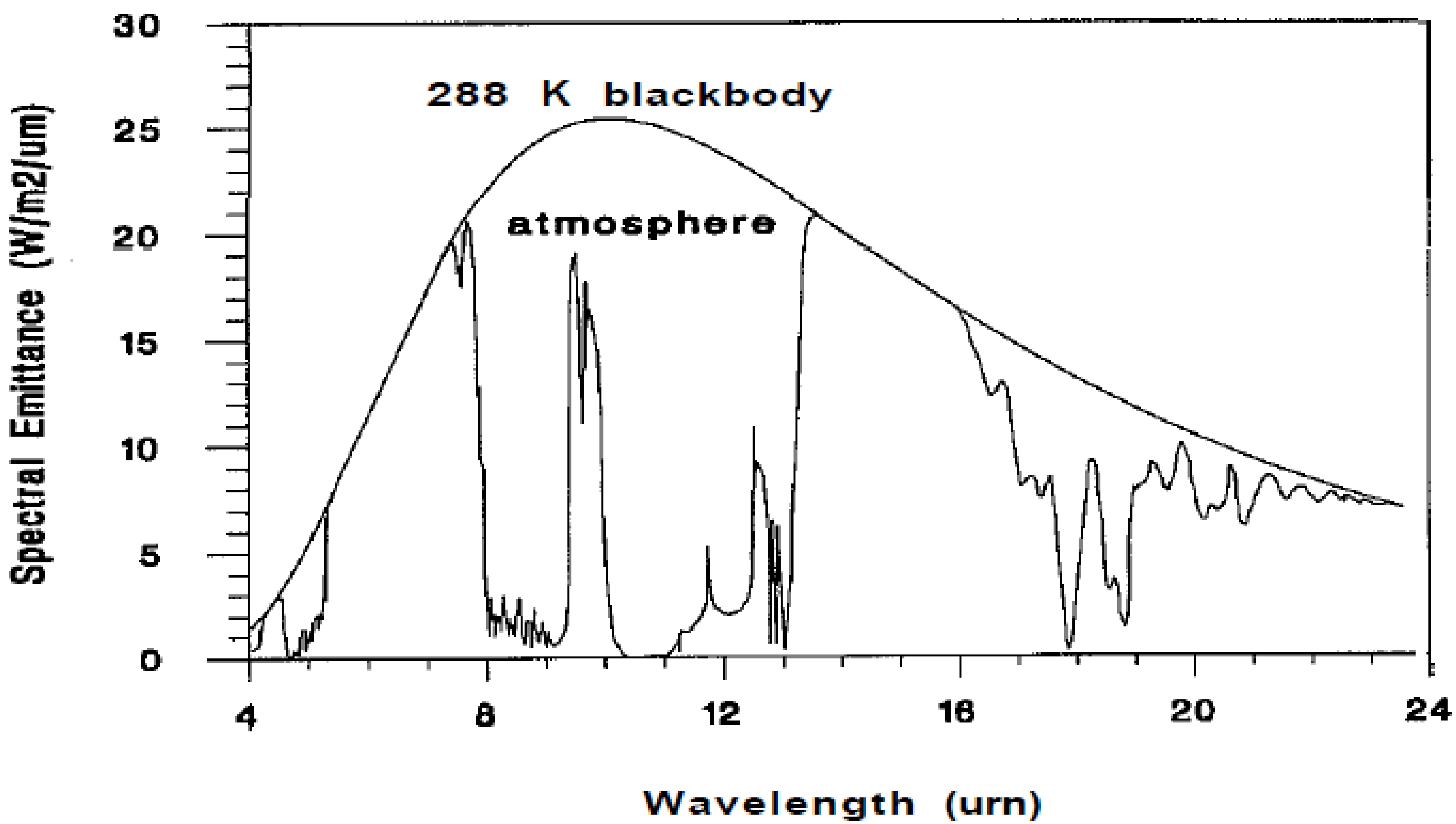


FIGURE 10.6. Spectral distribution of thermal radiation from the earth and from the clear atmosphere. Emission bands below 8 and above 18 μm are mainly from water vapor. Bands between 13 and 18 μm are mainly CO_2. The narrow band at 9.5 μm is from ozone (redrawn from Gates, 1962).

Radiation

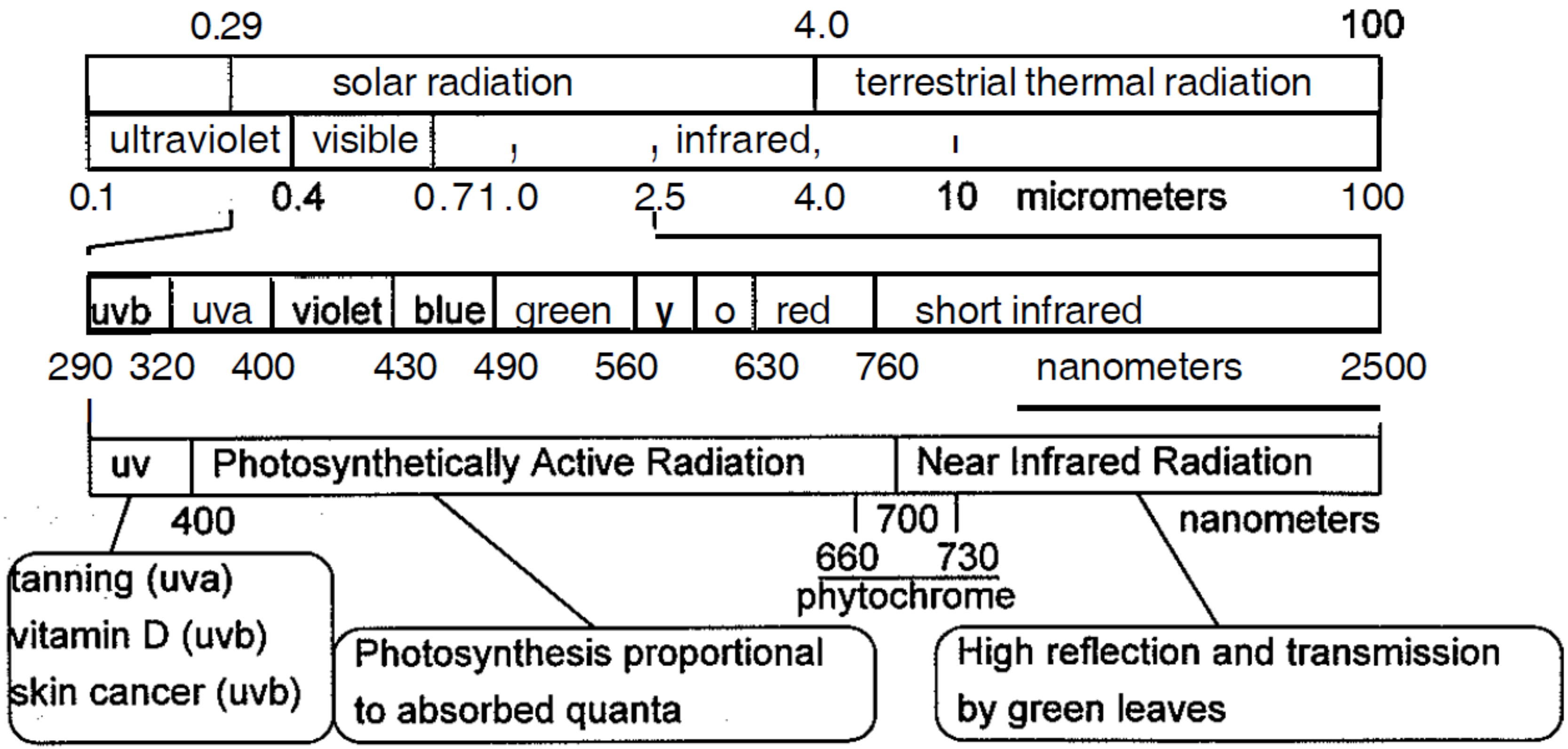


Figure 10.1. Part of the electromagnetic spectrum showing names of some of the wavebands and some of the biologically significant interactions with plants and animals.

Definitions and measures

- *Radiant flux* - radiant energy emitted, transmitted or received per unit time
- *Radiant flux density* - radiant flux per unit area
- *Irradiance* - radiant flux density incident on a surface
- *Radiant spectral flux density* - Radiant flux density per unit wavelength interval
- *Radiant intensity* - flux emanating from a surface per unit solid angle
- *Radiance* - radiant flux density emanating from a surface per unit solid angle
- *Spectral radiance* - radiance per unit wavelength interval
- *Radiant emittance* - radiant flux density emitted by a surface

Terminology

- Absorptivity [$\alpha(\lambda)$] - fraction of incident radiant flux at a given wavelength that is absorbed by the material
- Emissivity [$\varepsilon(\lambda)$]
- Reflectivity [$\rho(\lambda)$]
- Transmissivity [$\tau(\lambda)$]

Black body $\alpha(\lambda)=1$, $\rho(\lambda)=\tau(\lambda)=0$

$\varepsilon(\lambda)$: potential emissivity equals to $\alpha(\lambda)$.

Usually ε at longer λ than α because energy loss.

Commonly ε only in infrared range (thermal radiation).

Lambert's cosine law

$$\Phi = \Phi_0 \bullet \cos\theta$$

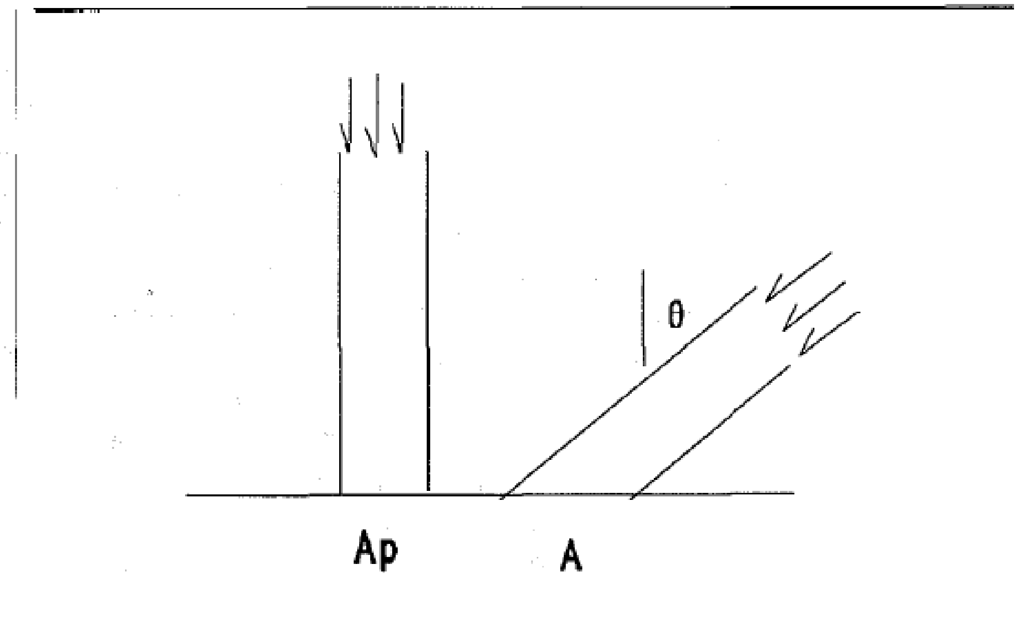


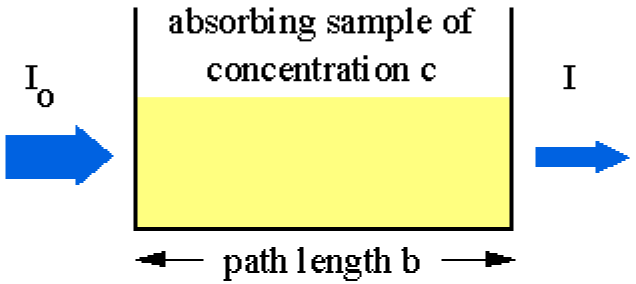
FIGURE 10.3. The area covered by a beam of parallel light increases as the angle θ between the beam and a normal to the surface increases.

Lambertian surface: ideal diffusely reflecting surface

$$\rho(\lambda) = a \bullet \cos \lambda$$

Beer-Lambert's Law

$$I = I_0 e^{-k * b}$$

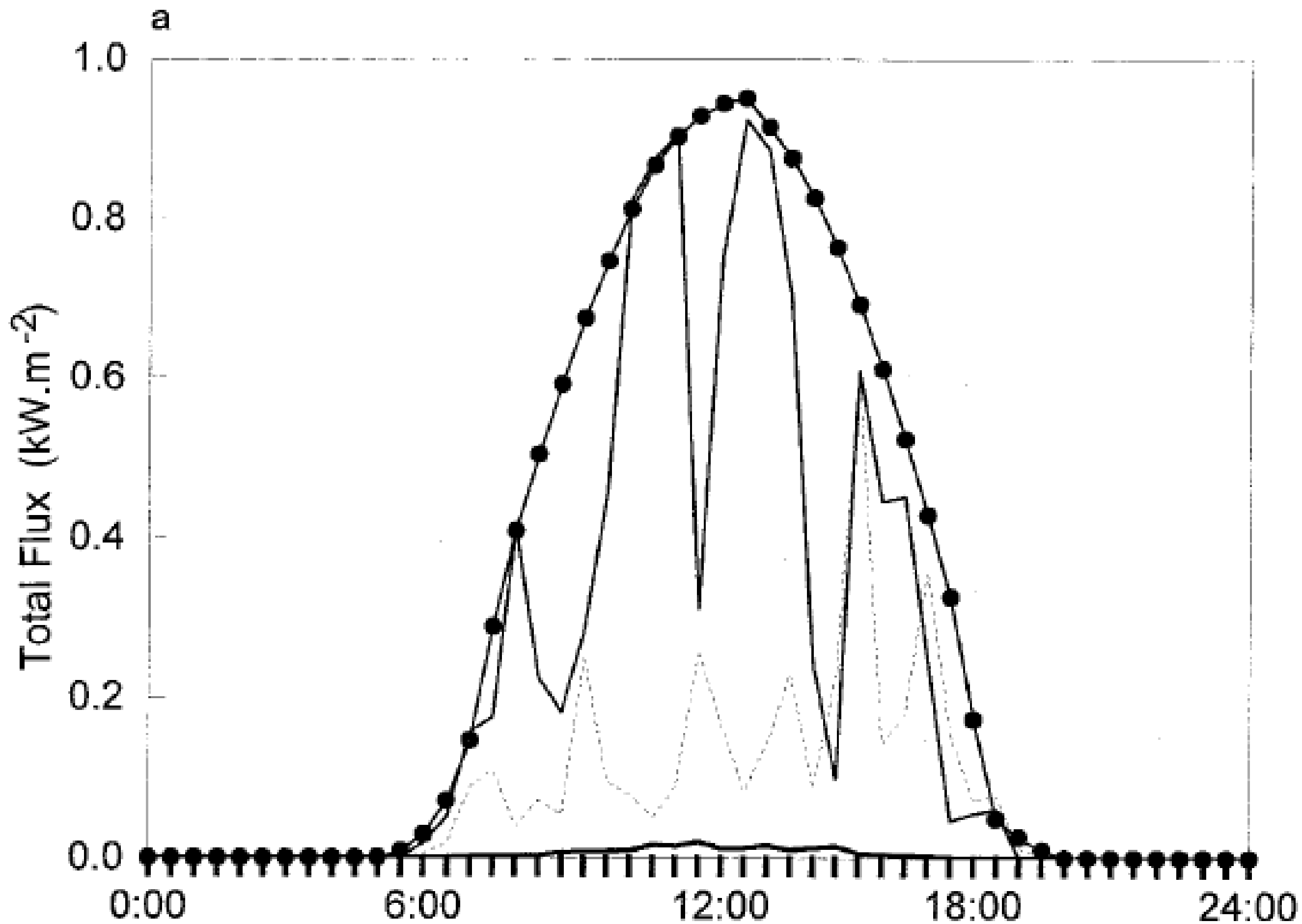


- Attenuation of radiation in a homogeneous medium
- Applies for wavebands narrow enough where ***k*** remains constant.

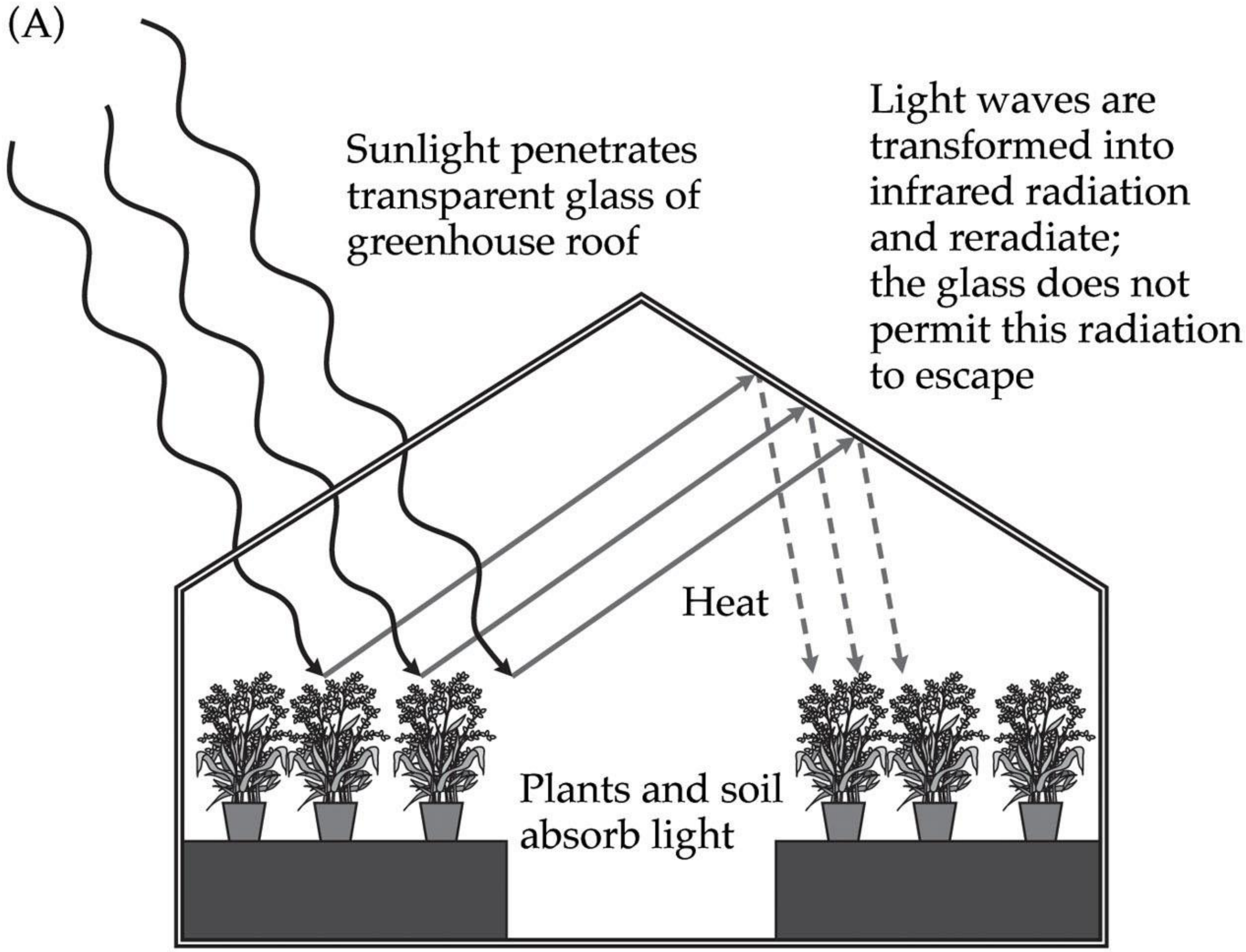
Hemispherical photos and applications: A "standard" method to characterize light environments beneath forest canopies

Demo of the solar.c model by Chen 1990.

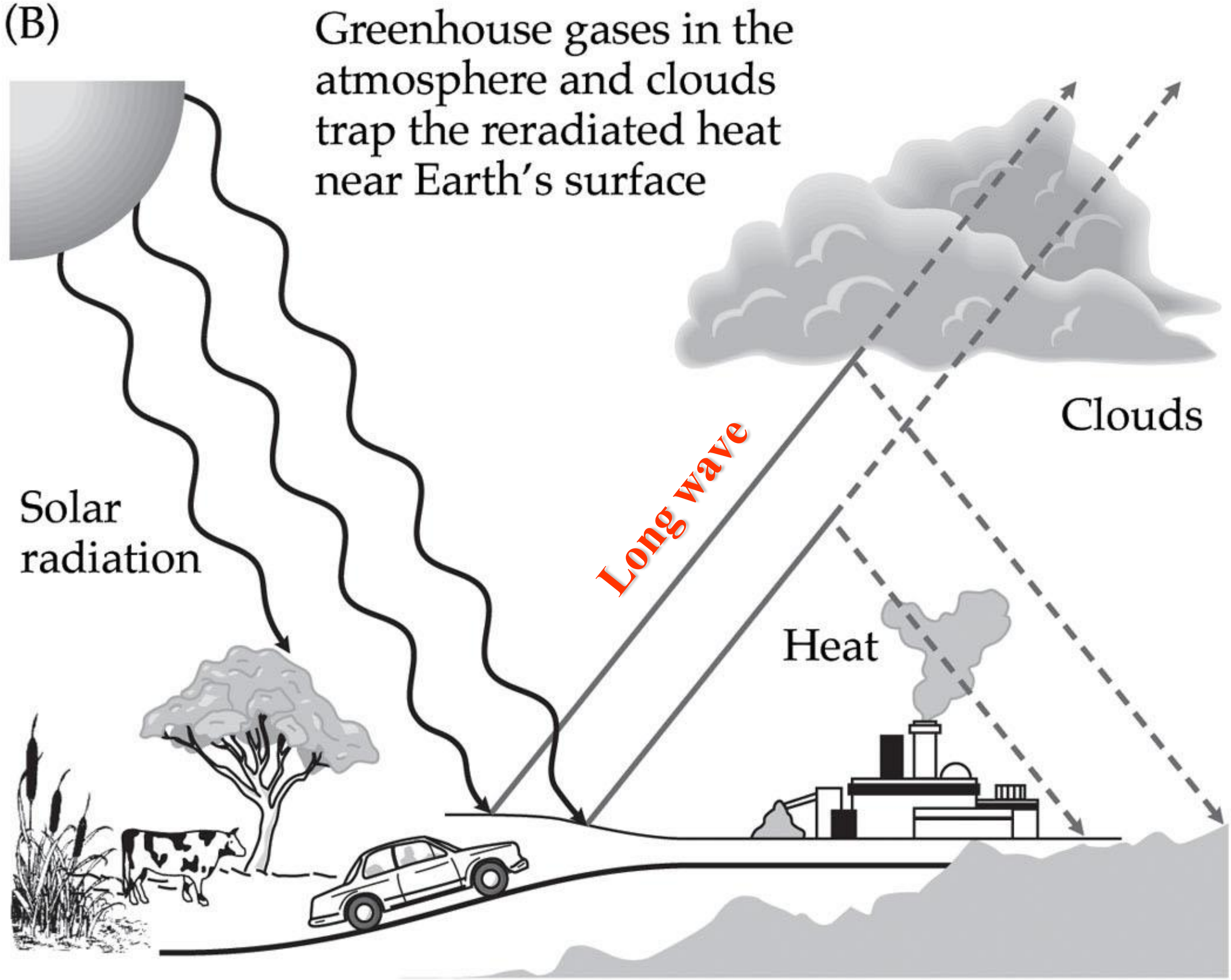
Diel change of short-wave radiation in and under forest canopies (Chen et al. 1999)



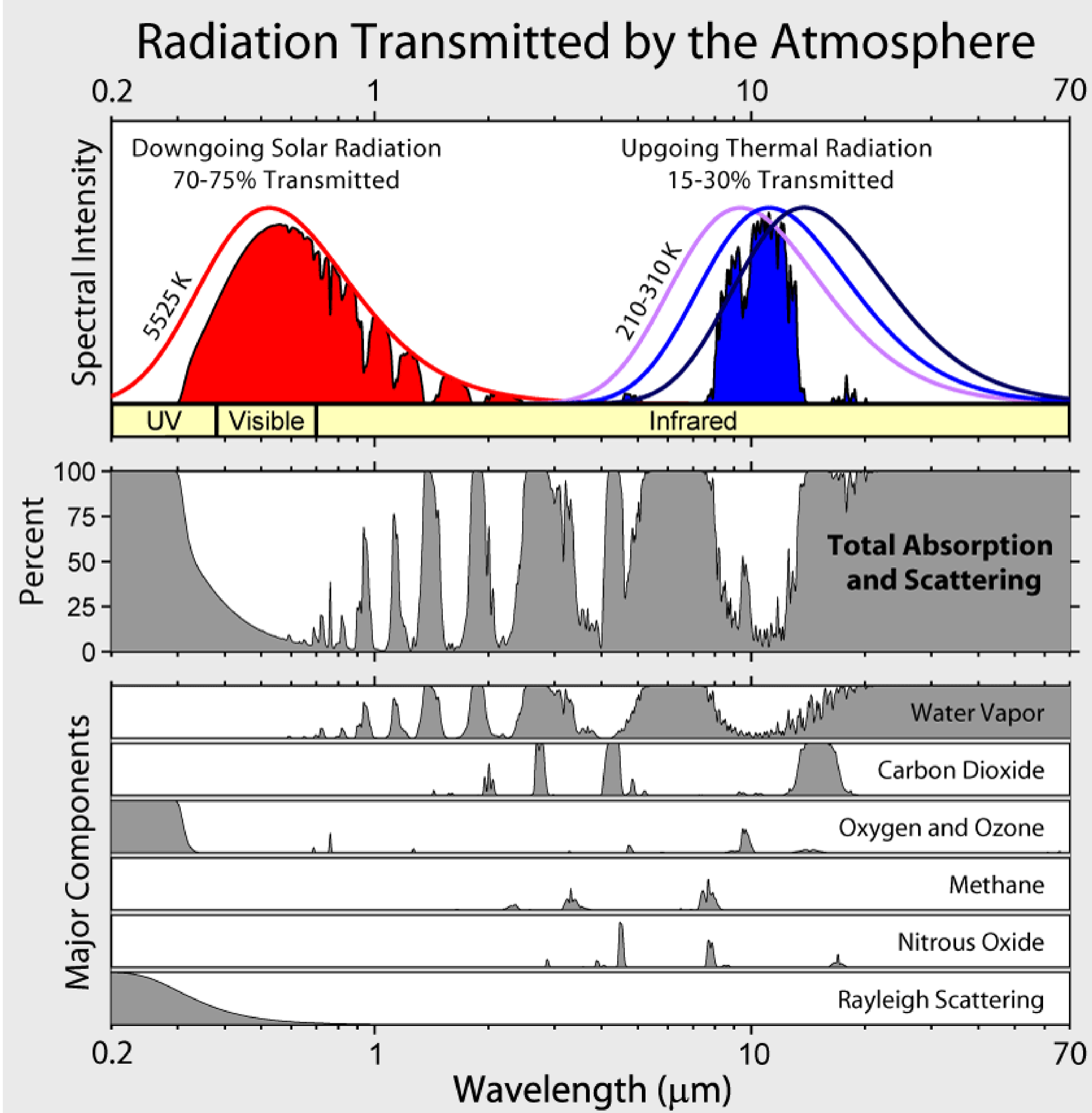
Greenhouse Effect



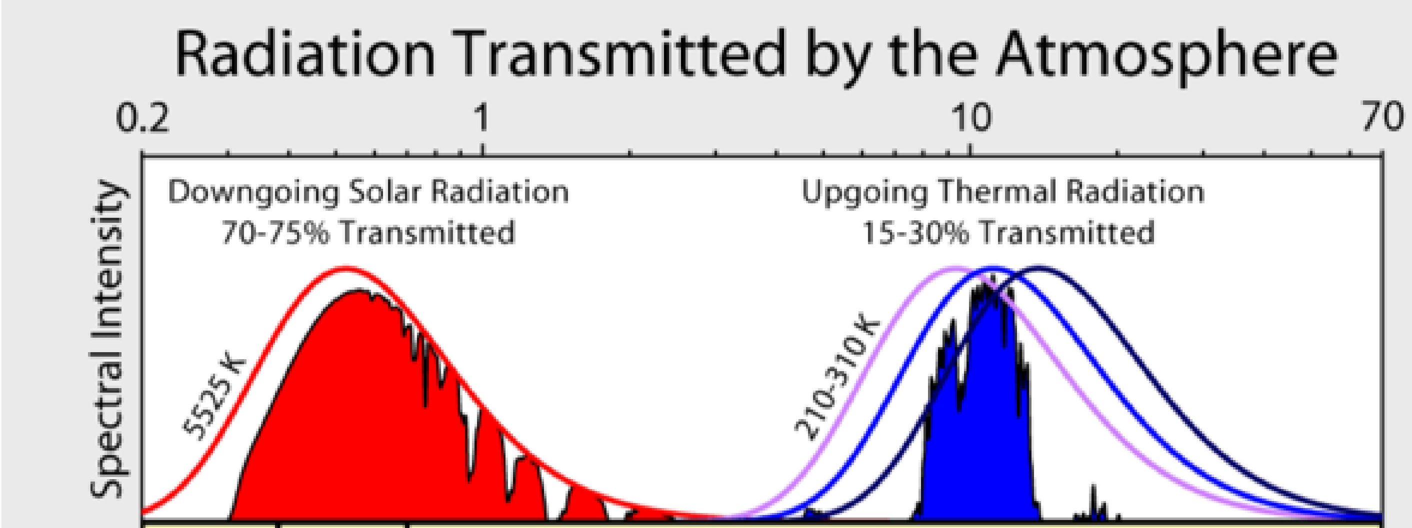
PRINCIPLES OF CONSERVATION BIOLOGY, Third Edition, Figure 10.1 (Part 1)

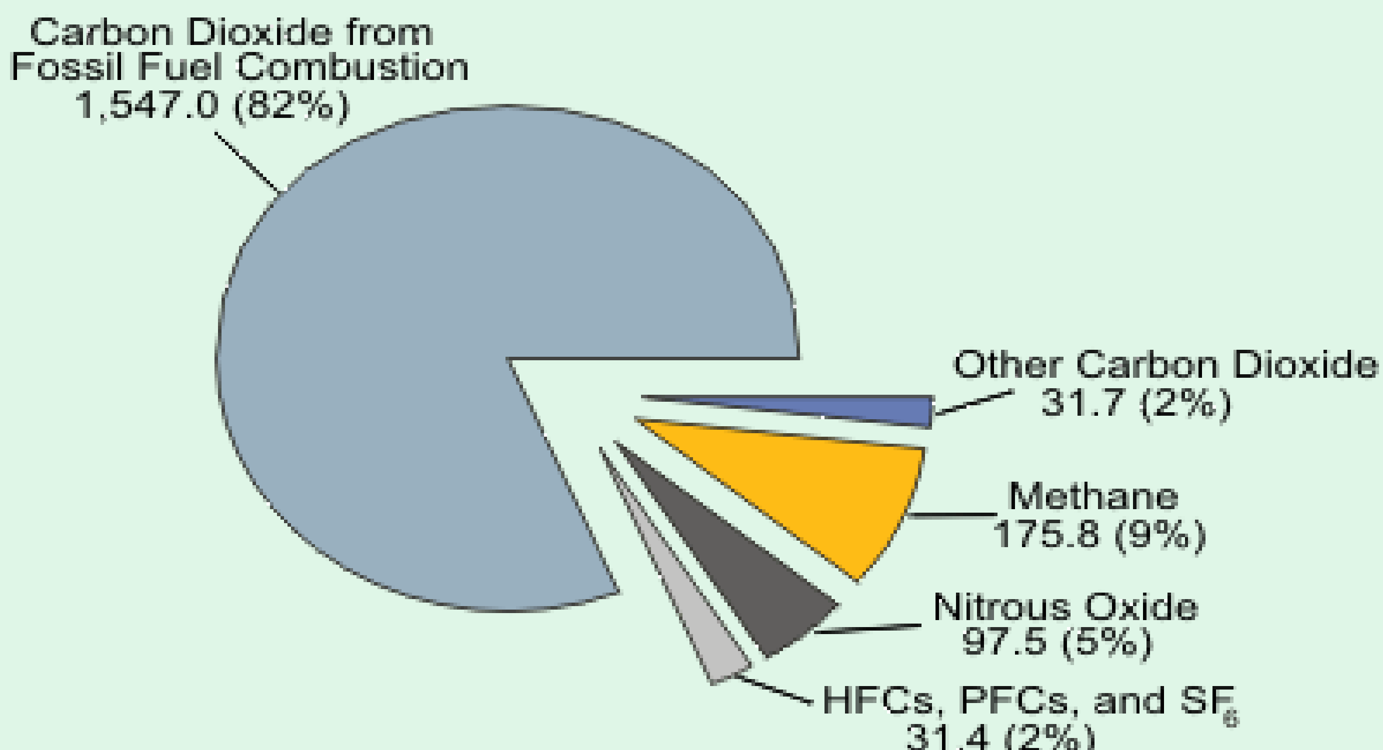


Light waves are transformed into infrared radiation reflected back to Earth by clouds and reradiated



http://www.epa.gov/climatechange/emissions/usinventoryreport.html





Source: Energy Information Administration, Emissions of Greenhouse Gases in the United States 2001 (Washington, DC, 2002

Radiometers

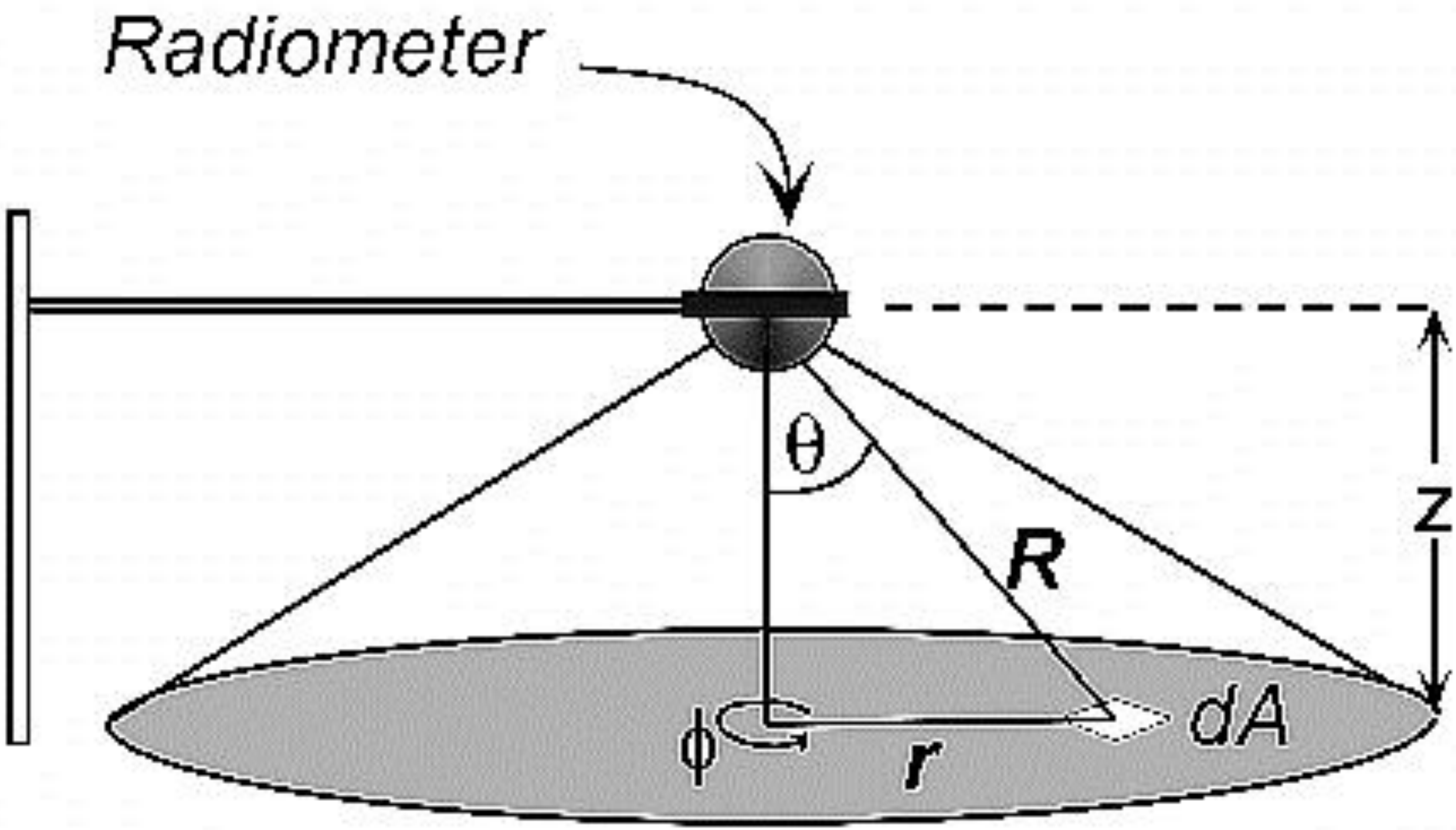
- Pyranometer: Global shortwave radiation
- Pyrheliometer: direct beam of solar radiation
- Pyrgeometer: measurement of longwave radiation
- Net radiometer: difference between incoming and outgoing radiation
- Diffuse radiation: pyranometer and shadow bands
- Hemispherical photos:

View factors

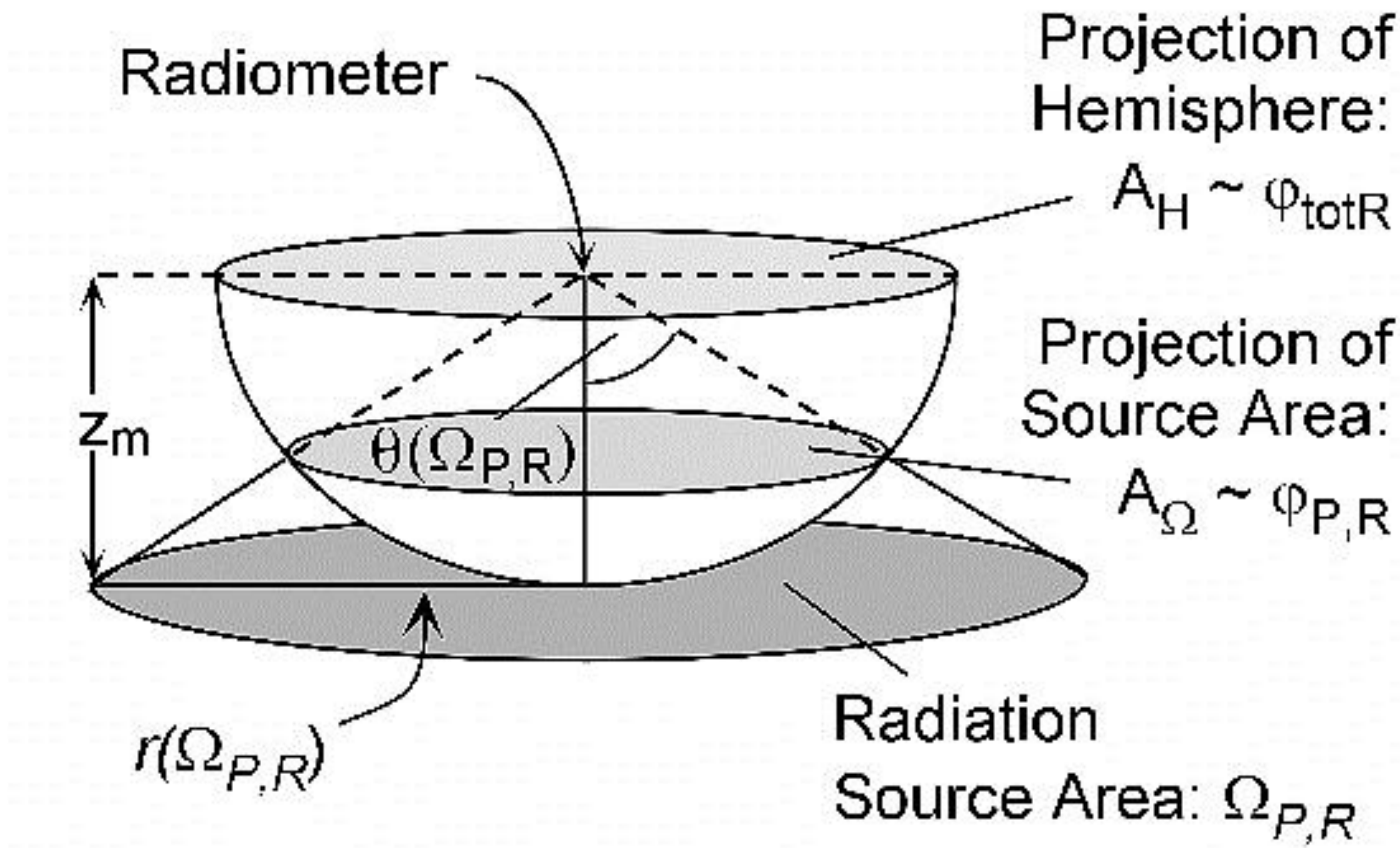
- Radiation from one object gets intercepted by another
- View factor = average flux density over the entire surface of the object divided by flux density on a flat absorbing surface facing the source.
- For beam radiation this is numerically equal to the ratio of projected area (in the direction of the source of the radiation) to total surface area
- The sum of view factors of an object to its surrounding environment is **1**

- For canopy, $F_r = F_g = 0$; $F_a = F_d = (1+\cos g)/2$; $F_e = 1$
- For leaf, $F_p = 0.5 \cos q$; $F_a = F_d = F_r = F_g = 0.5$; $F_e = 1$
- $q = f$\{zenith angle; azimuth angle; aspect angle; inclination angle\}

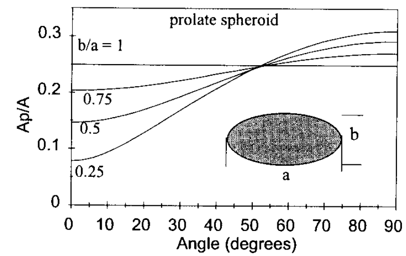
The geometrical arrangement of a radiometer above a flat, horizontal surface. Refer to the text for definitions of the geometrical elements.



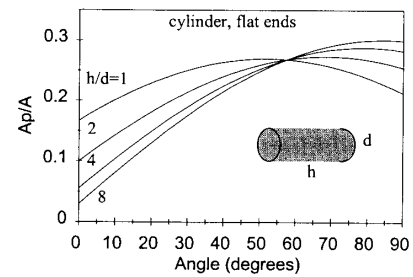
The geometrical derivation of the radiation source area (eq. (A8). The source area level *P* is the ratio of the projection of the source area onto the lower hemisphere and then onto the radiometer plane (A_W), to the projection of the entire hemisphere onto the radiometer plane (A_H).



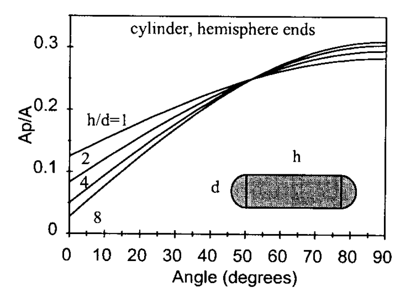
View factors



$$\frac{A_p}{A}=\frac{\sqrt{1+(x^2-1)\cos^2\theta}}{2x+\frac{2\sin^{-1}\sqrt{1-x^2}}{\sqrt{1-x^2}}}\quad ; \quad x=b/a$$



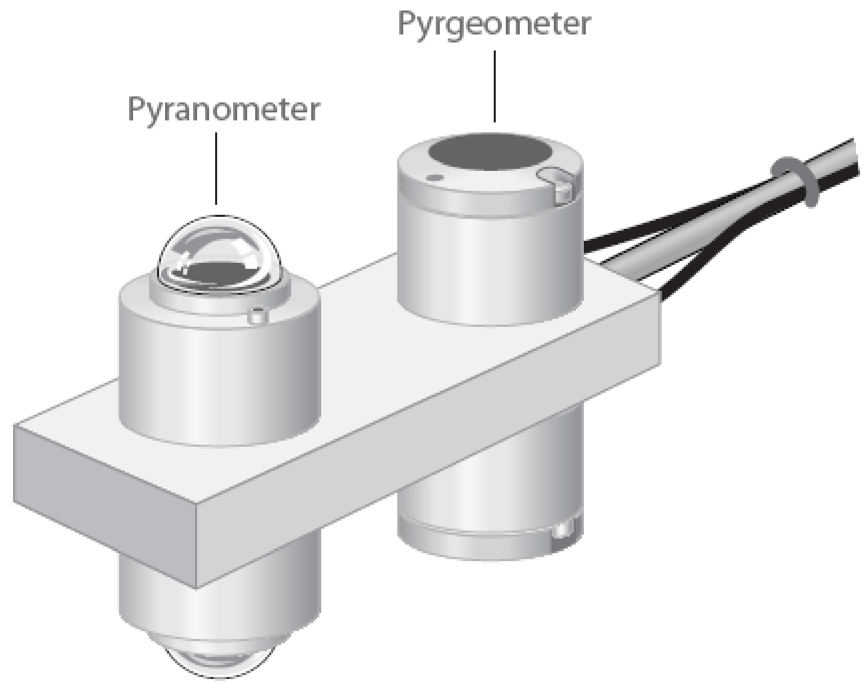
$$\frac{A_p}{A}=\frac{\cos\theta+\frac{4h\sin\theta}{\pi d}}{2+\frac{4h}{d}}$$



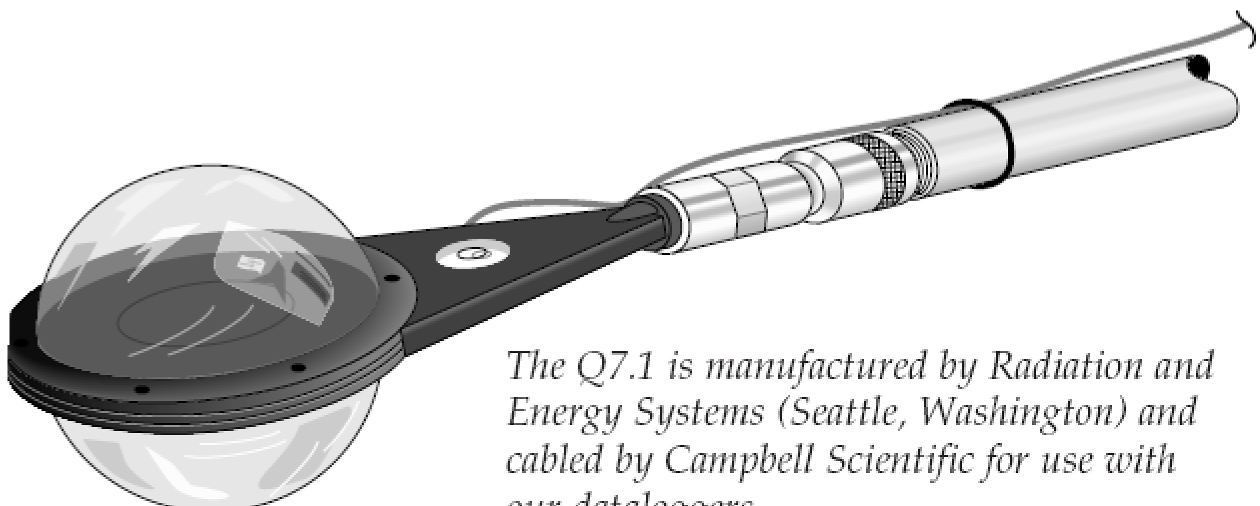
$$\frac{A_p}{A}=\frac{1+\frac{4h\sin\theta}{\pi d}}{4+\frac{4h}{d}}$$

FIGURE 11.6. Ratios of shadow area on a surface perpendicular to the solar beam to total surface area for three simulated animal shapes. The angle indicated is the angle between the solar beam and the longitudinal axis of the solid.

The CNR1 net radiometer is manufactured by Kipp & Zonen for applications requiring research-grade performance. The radiometer measures the energy balance between incoming short-wave and long-wave infrared radiation versus surface-reflected short-wave and outgoing long-wave infrared radiation. The CNR1 consists of a pyranometer and pyrgeometer pair that faces upward and a complementary pair that faces downward.

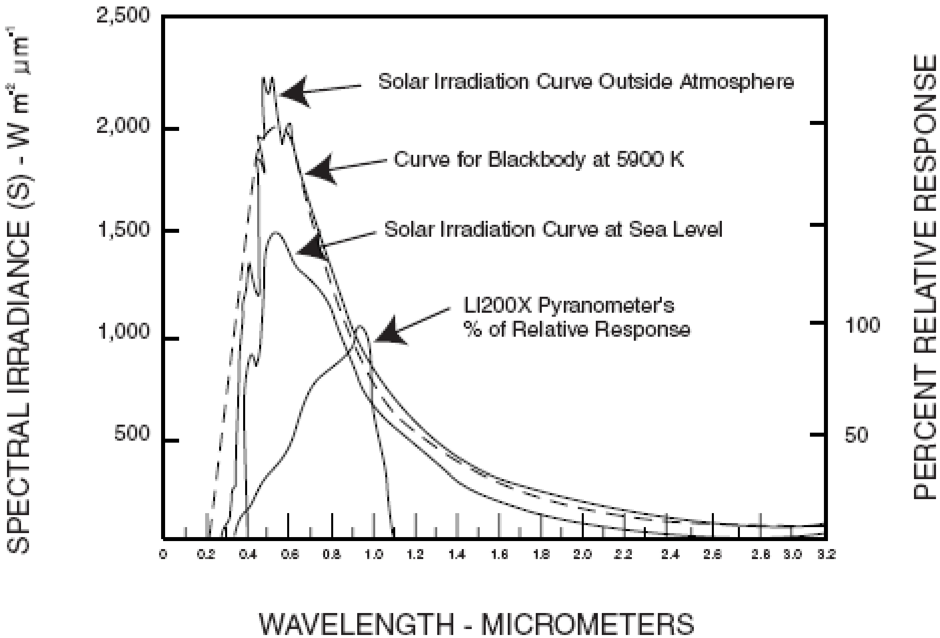


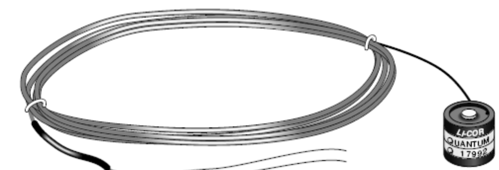
The Q7.1 is an high-output thermopile sensor that generates a millivolt signal proportional to the net radiation level. The sensor is mounted in a glass-reinforced plastic frame with a built-in level. A ball joint is supplied on the stem to facilitate leveling. The sensor surface and surrounding surfaces are painted flat black to reduce reflections within the instrument and to achieve uniform performance over reflective and non-reflective surfaces.



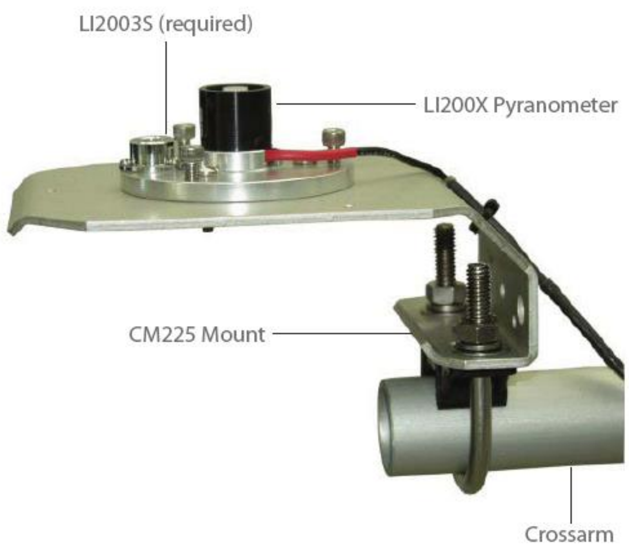
The Q7.1 is manufactured by Radiation and Energy Systems (Seattle, Washington) and cabled by Campbell Scientific for use with our dataloggers.

LI200X Spectral Response





The LI190SB Quantum Sensor is shown above. The LI200X has a similar appearance.



LI190SB Spectral Response

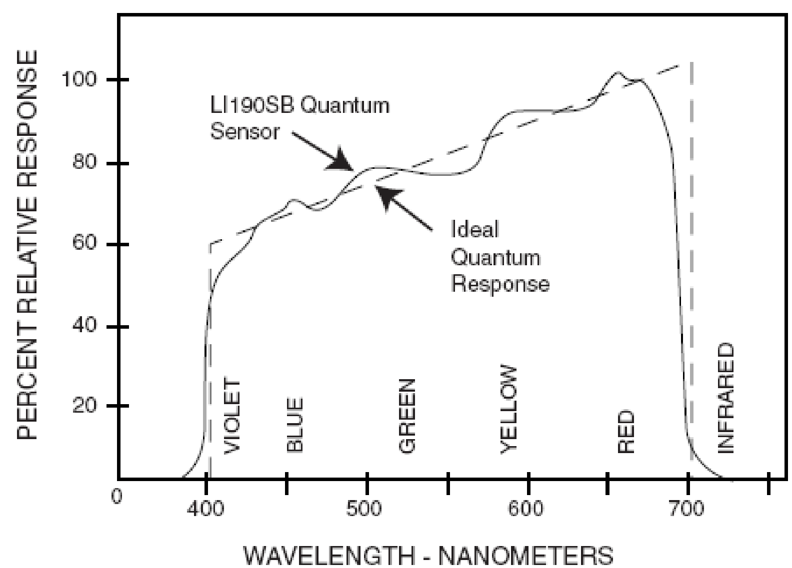


Figure 1: Photo of two different pyronometers for measuring global horizontal solar radiation. The foreground instrument is a Black and White pyronometer and the deeper one is a Precision Spectral pyronometer. Photo by T. Stoffel. Source of photo DOE/NREL.

Figure 2: Photo of several pyrheliometers for measuring direct solar radiation. Photo by T. Stoffel. Source of photo DOE/NREL

Fig. 1.38 Pyranometer and occulting ring according to a design by Horowitz (1969).