Sunlight

PHYS 4400, Principles and Varieties of Solar Energy

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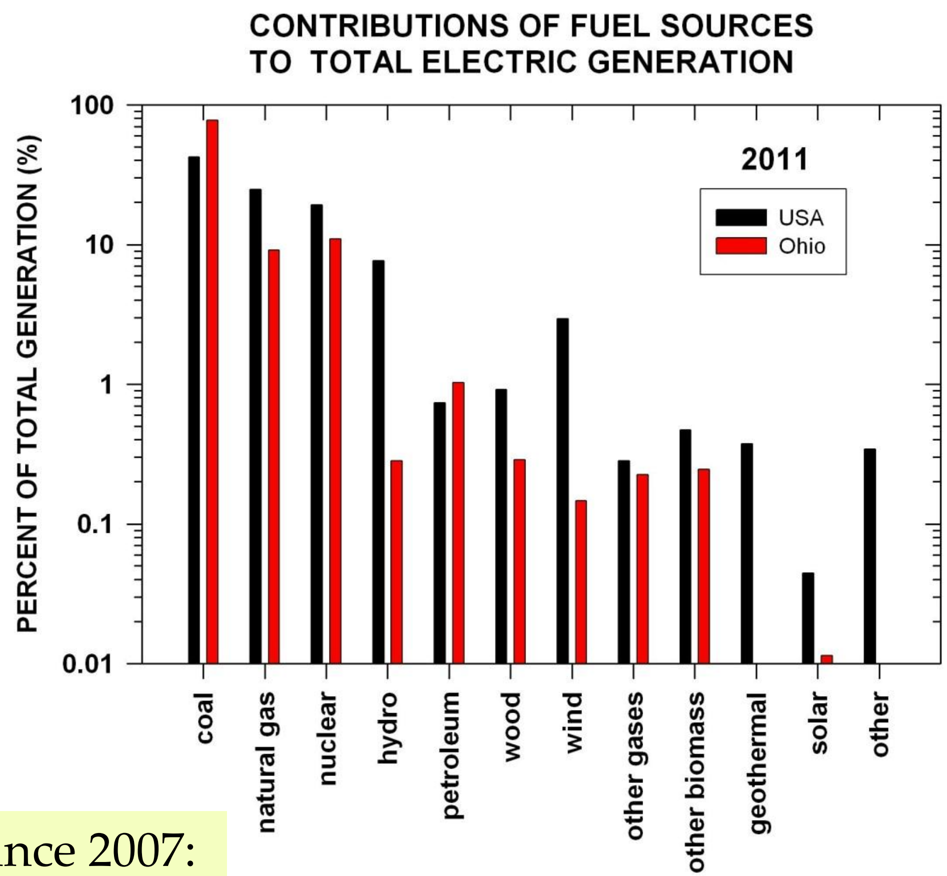
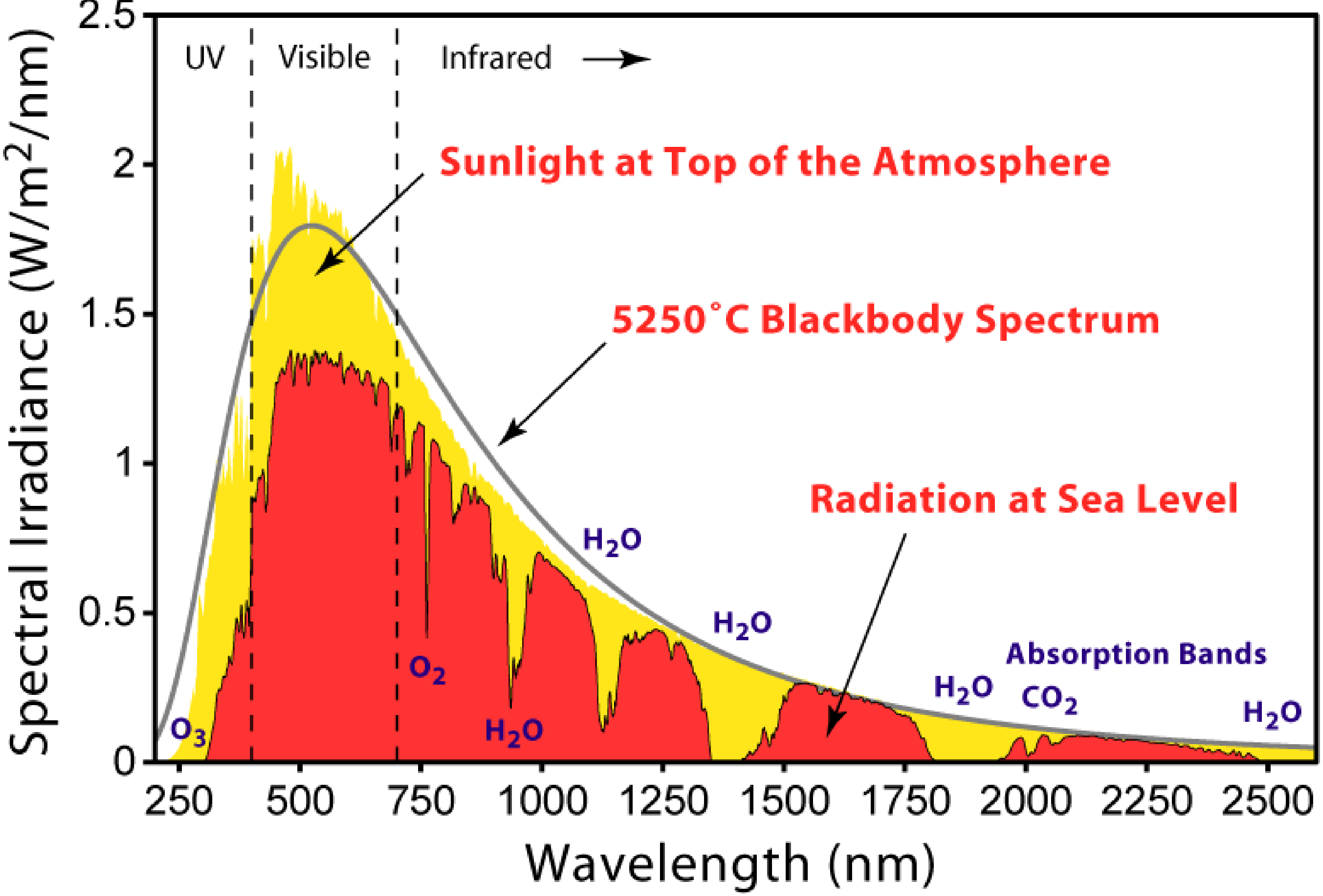
Update on Ohio's fuels for electricity generation



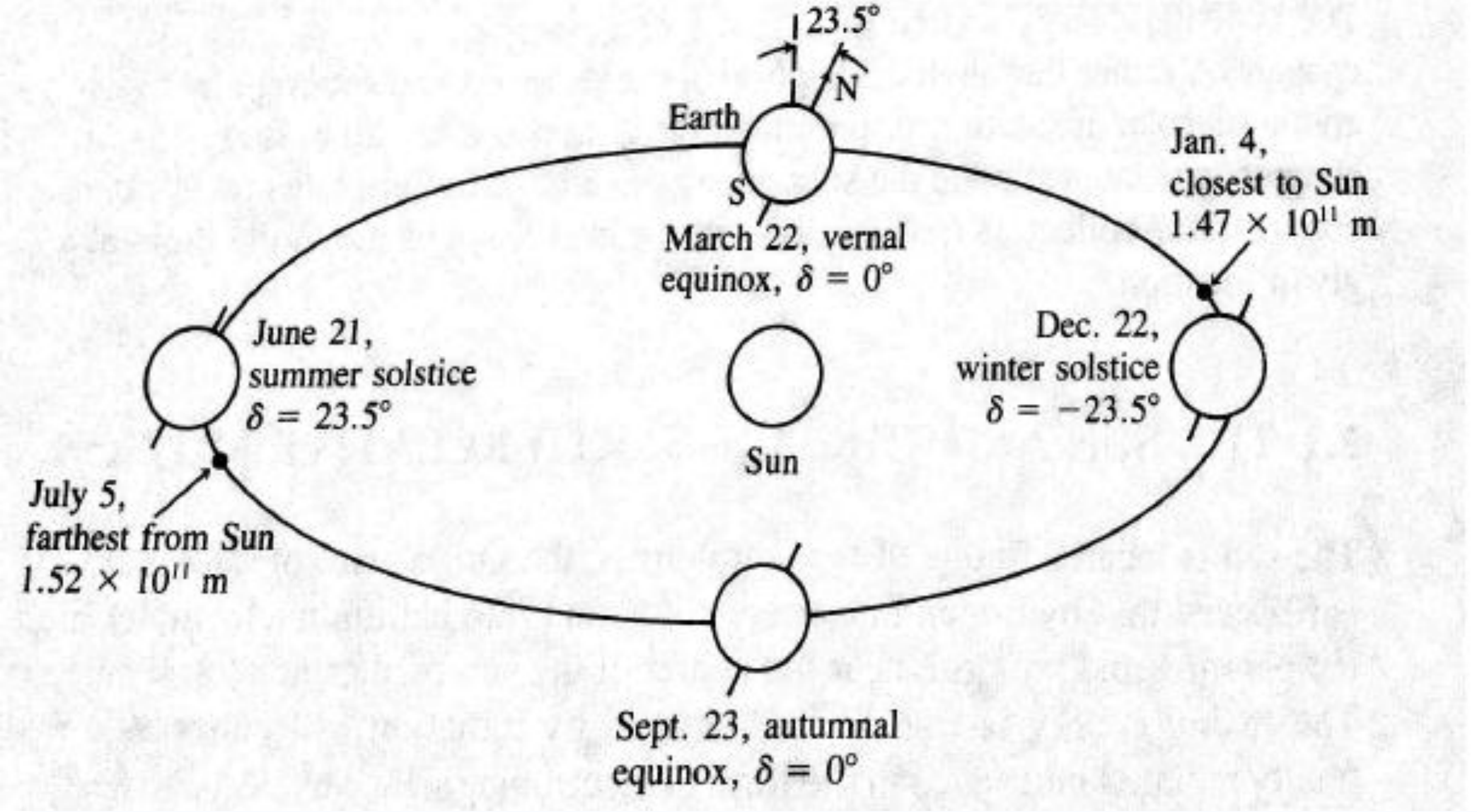
Trends observed since 2007:

- Coal is still dominant, but its share is declining.
- Natural gas is number 2, and its share is rising.
- Nuclear is flat.
- Wind is rising rapidly, and now (as of 2011) stands at about 3% of the total electric production nationally (10% in Colo.)
- Solar is rising, but still very small at less than 0.1% nationally.

Solar Radiation Spectrum



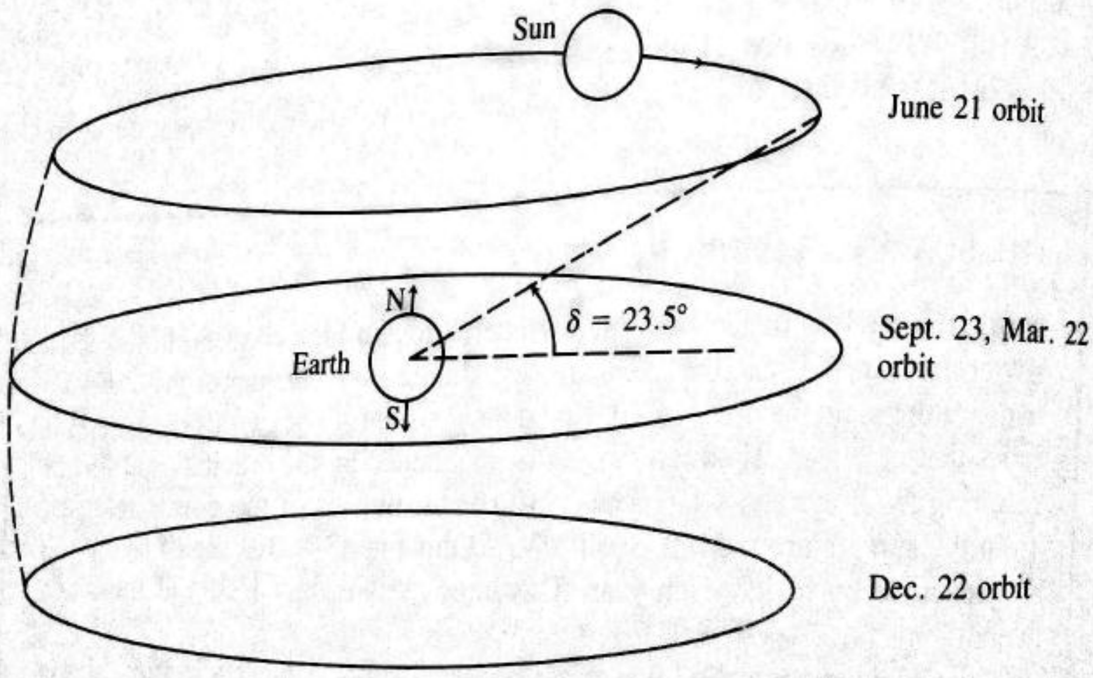
Earth's Motion around the Sun



δ = angle of declination between Sun's rays and the plane of the equator

From "Solar Cells", by C. Hu and R.M. White

After Coordinate Transformation (earth-centric view)



(*b*)

Figure 2.1 (*a*) The conventional sun-centered view of the sun-earth system. (*b*) An earth-centered view, which is easier to visualize. For example, the declination angle δ between the sun ray and the plane of the equator is better illustrated in *b*. The date given may vary by one day or so.

From “Solar Cells”, by C. Hu and R.M. White

Daily Variation in Energy Collection

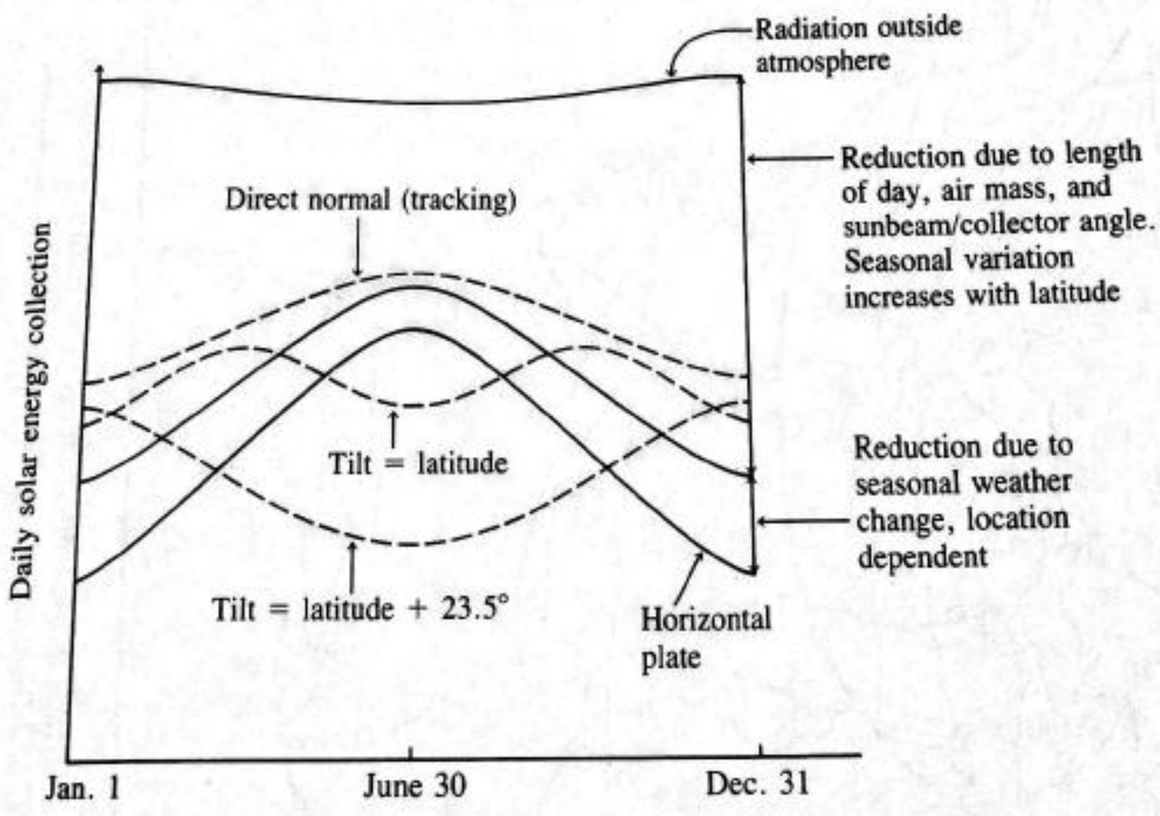
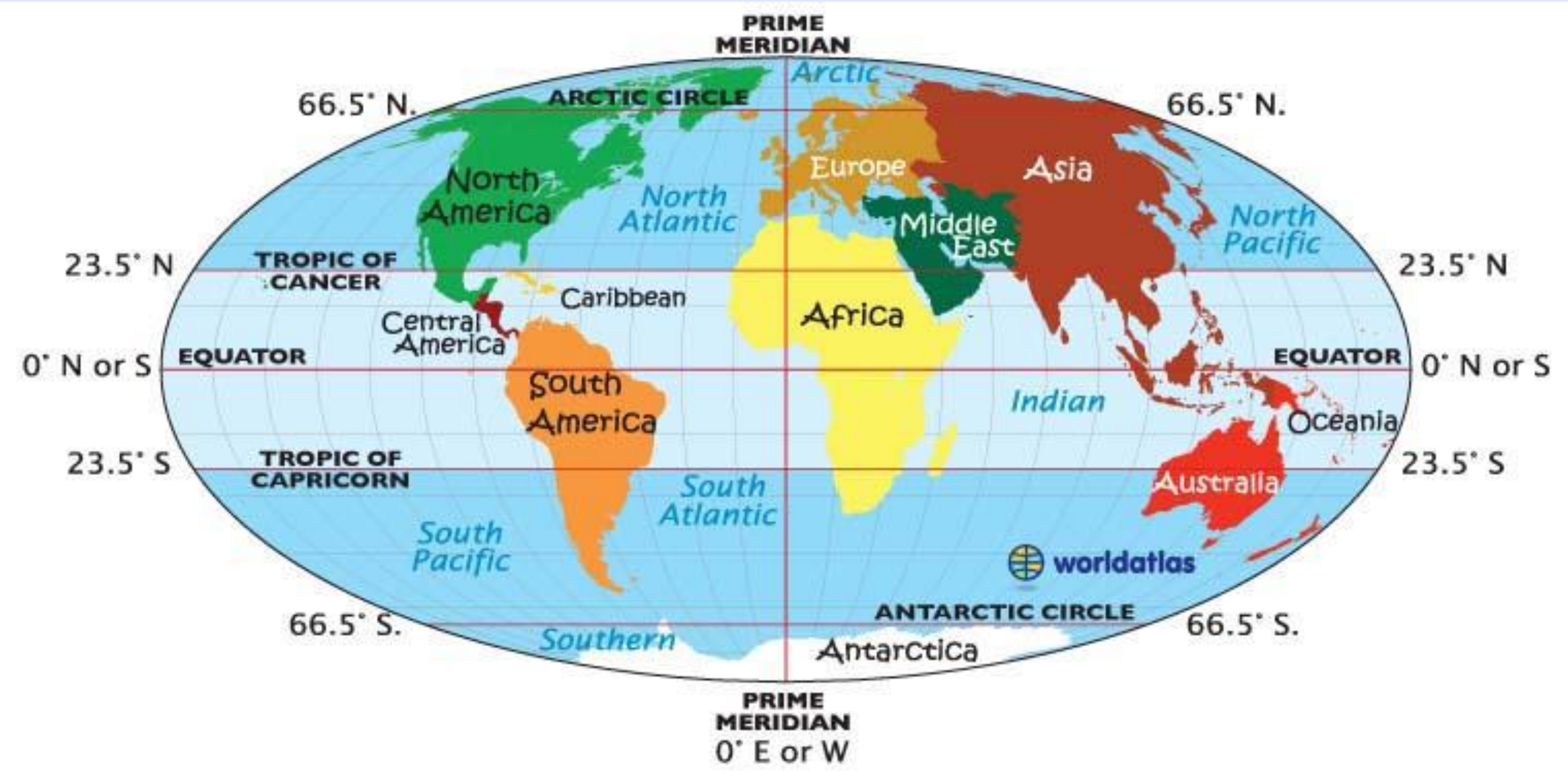


Figure 2.7 Qualitative plots of seasonal variations of daily solar energy collection for a location north of 23.5°N. "Tilt" (see Sec. 2.5) is the angle between the collector plate and the horizontal plane. The plate is tilted due south.

From "Solar Cells", by C. Hu and R.M. White



http://www.worldatlas.com/aatlas/imagee.htm

Solar Constant

We've been informed that the total luminous power output from the Sun is 3.846×10^{26} W.

Now we'd like to determine the portion of that power incident on Earth, and the average areal intensity (i.e., averaged over the area of Earth's surface).

From in-class exercises, we figured out the solar constant (~1.75×10^{17} W).

We found that the intensity of sunlight arriving at the top of Earth's atmosphere is 1.375 kW m^{-2}.

We determined the intensity of arriving sunlight averaged over Earth's total surface area to be 343 W m^{-2}. (averaged over the total area of the Earth, and averaged over day and night).

$r_{Earth} = 6.37 \times 10^6$ m
1 AU = 1.496×10^{11} m

Standard solar spectra

Sunlight varies with factors including location, weather, and the time of day.

Standard solar spectra are defined to enable comparison of materials and device performance among manufacturers and laboratories around the world.

There are standard for extraterrestrial and terrestrial sunlight:

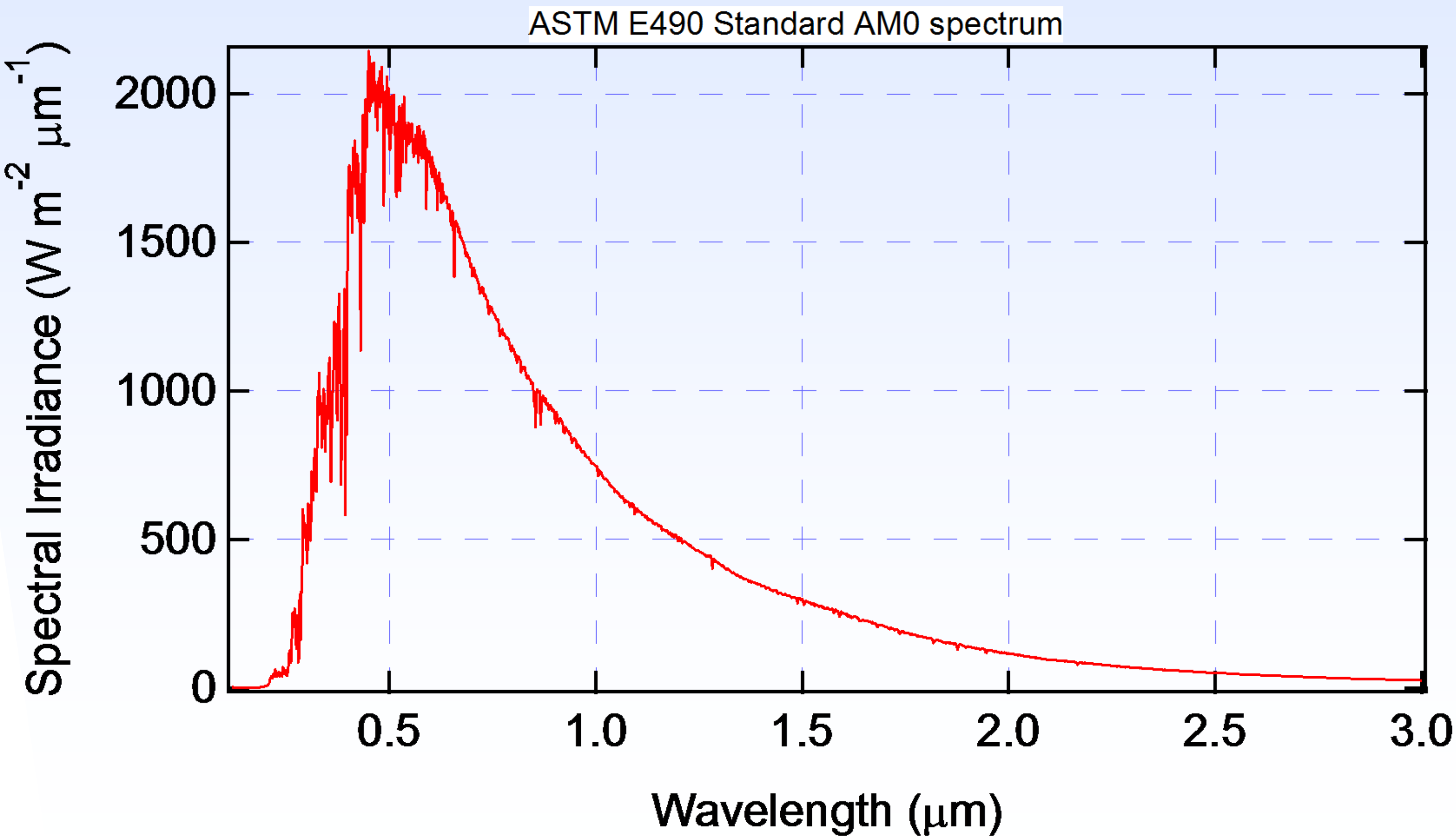
Extraterrestrial: this spectrum, referred to as AM0, defines sunlight just above Earth's atmosphere, where the sunlight has an intensity dependent on the solar constant.

Terrestrial: refers to sunlight which has passed through Earth's atmosphere. There are two standard solar spectra, referred to as AM1.5G (G stands for Global Tilt), and AM1.5 Direct (+circumsolar).

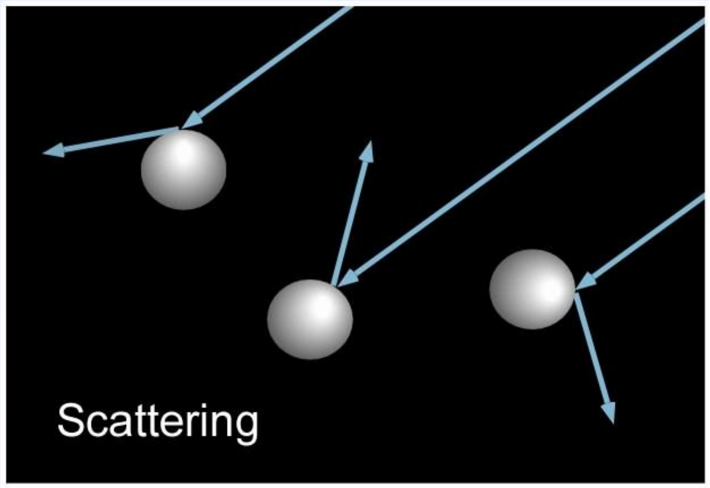
AM0: the spectrum above Earth's atmosphere

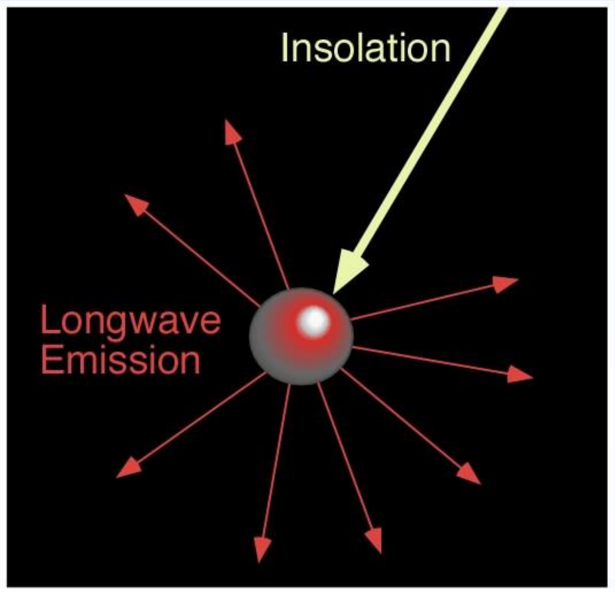
The AM0 spectrum applies to satellites and high-flying aircraft, which access the spectrum prior to any influence from Earth's atmosphere.

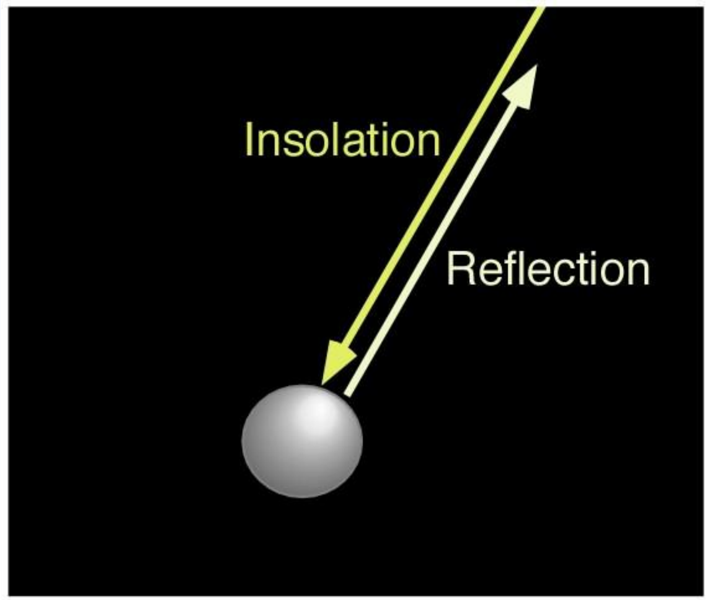
Integrated spectral irradiance = 1366 W/m^2.

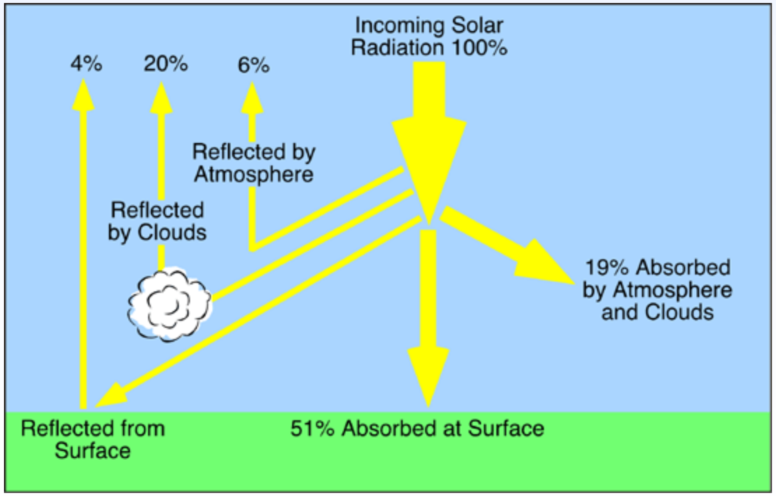


Atmospheric effects on sunlight



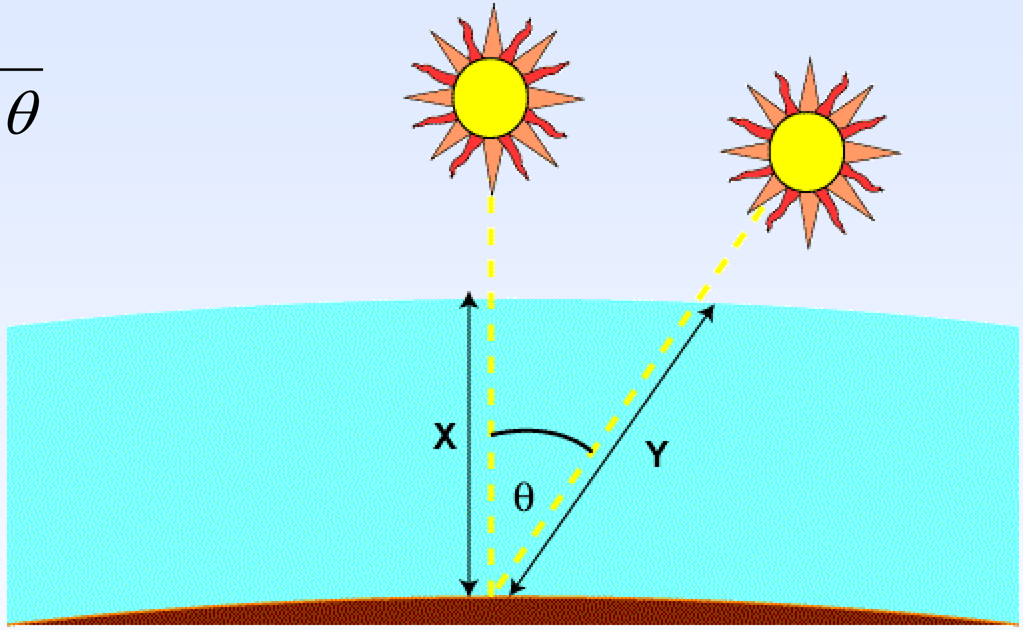






Air Mass

$$AM = \frac{1}{\cos\theta}$$

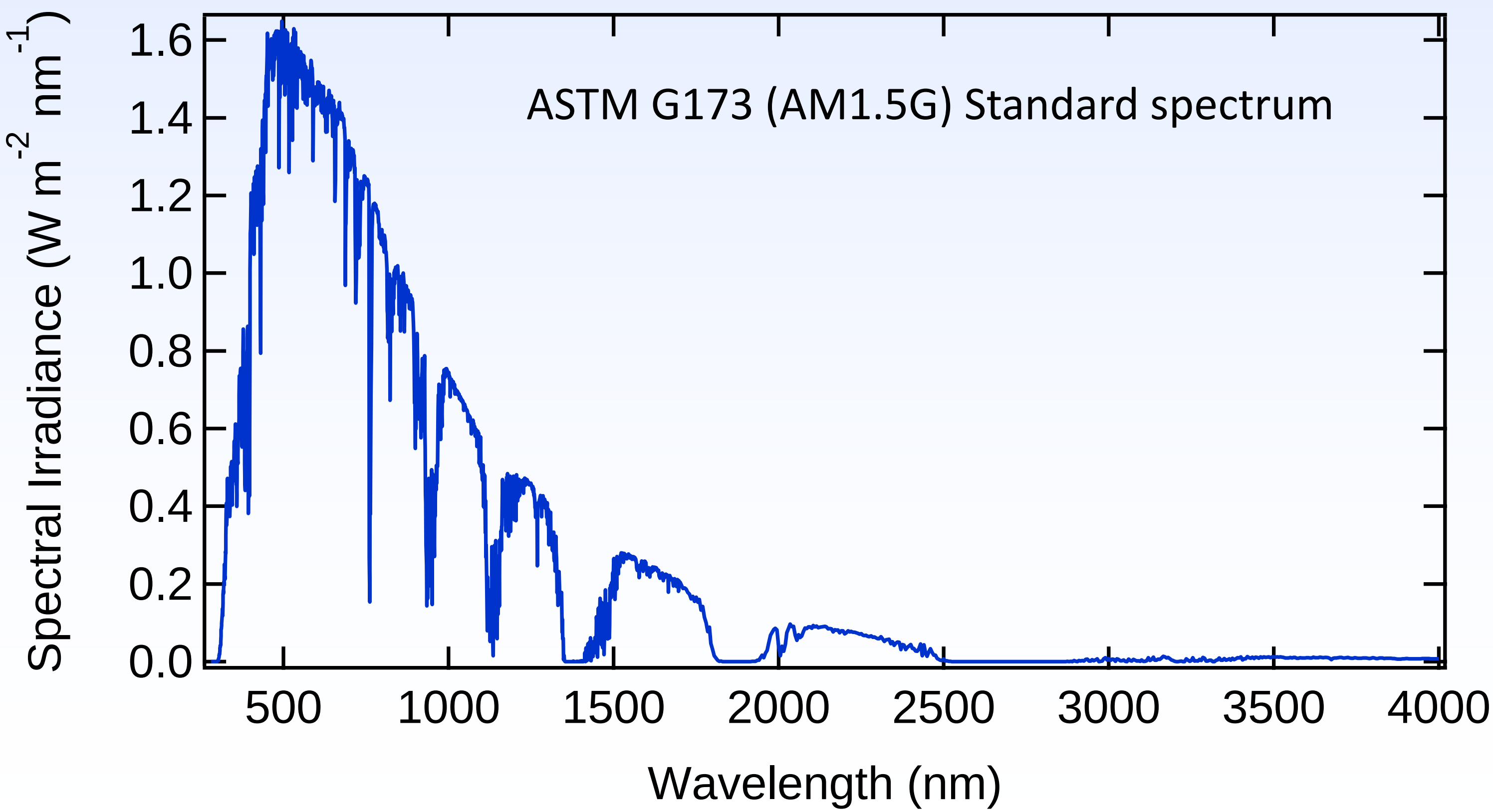


Does AM = ∞ when θ = 90°?

$$AM = \frac{1}{\cos\theta + 0.5057(96.07995 - \theta)^{-1.6364}}$$

AM1.5G: reference spectrum including direct and diffuse sunlight

- AM 1.5: From the equation provided for Air Mass, one calculates that cos θ = 0.667, so that θ = 48.2°. This represents the zenith angle, that it, the angle relative to the direction normal to Earth's surface.
- Toledo latitude: 41.6639 ° N
- Integrating the energy within AM1.5G yields 1000 W m^{-2}.



AM1.5D: reference spectrum including direct and circumsolar diffuse sunlight

Includes sunlight scattered within 2.5° angle of the direct sunlight. Used for clear days, relevant to concentrated sunlight applications for which the ability to focus the sunlight depends critically on the direction the light is traveling.

$$I_G = 1.1 \cdot I_D$$