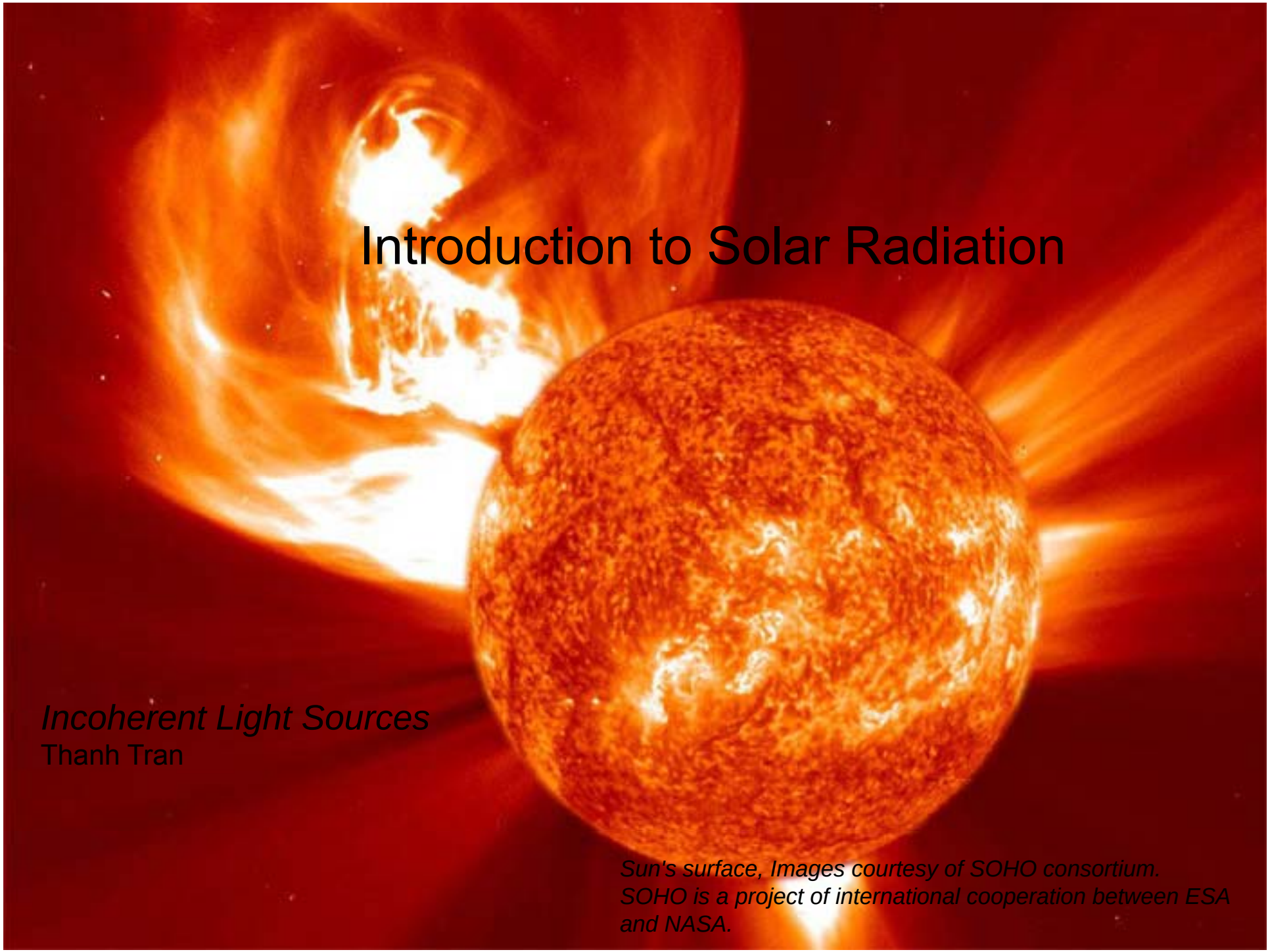
Introduction to Solar Radiation



Incoherent Light Sources

Thanh Tran

Sun's surface, Images courtesy of SOHO consortium. SOHO is a project of international cooperation between ESA and NASA.

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  - The sun
  - Blackbody radiation
- The solar radiation spectrum
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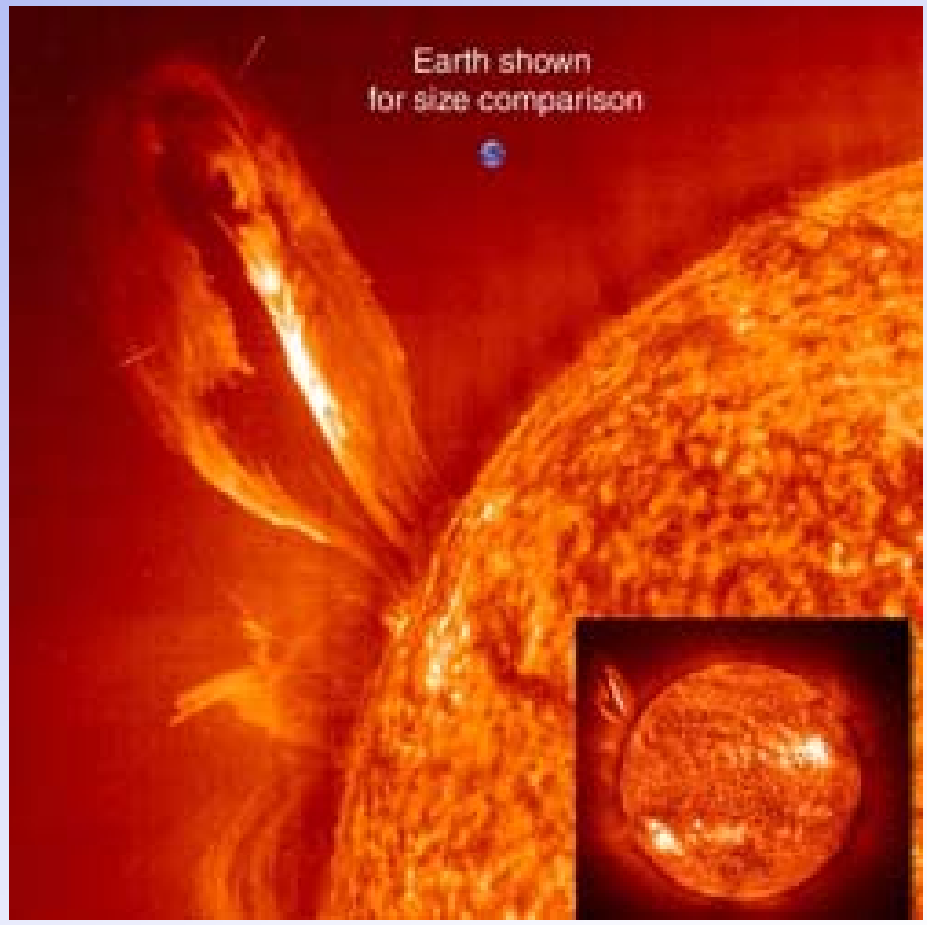
Introduction

- The **sun** is a gaseous body composed mostly of **hydrogen**
- Gravity causes intense pressure and heat at the core initiating nuclear fusing reactions
- This means that atoms of lighter elements are combined into atoms of heavier elements, which releases enormous quantities of energy



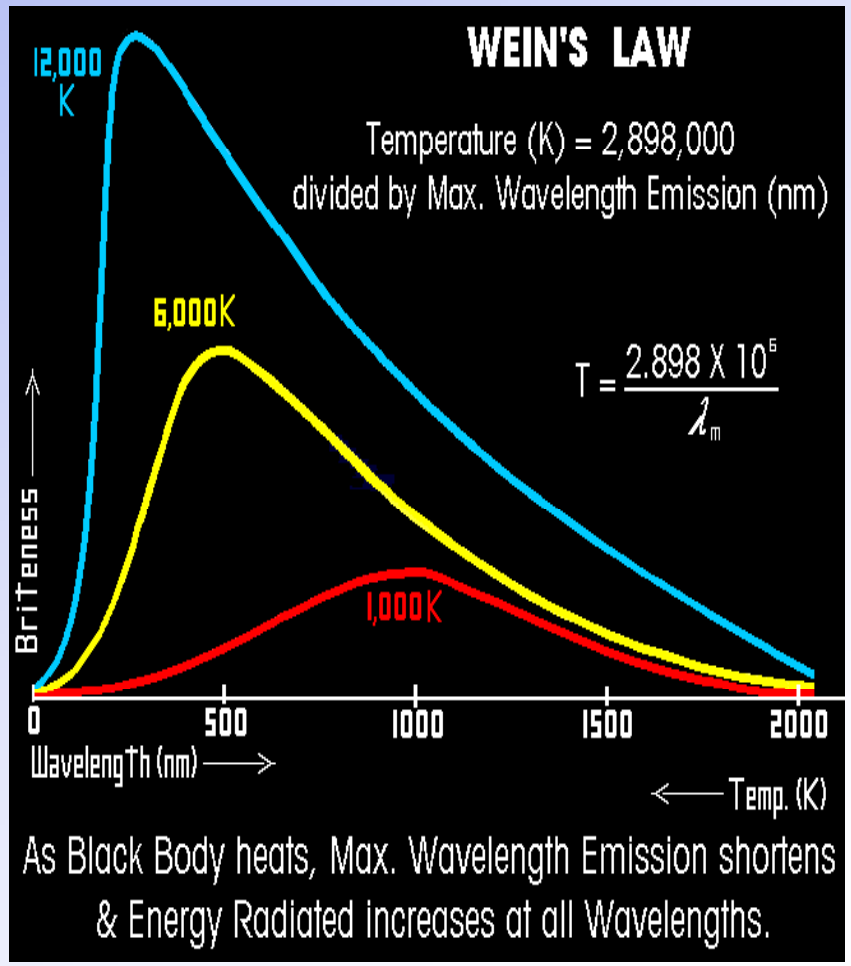
Sun's surface, Images courtesy of SOHO consortium. SOHO is a project of international cooperation between ESA and NASA.

Black body Radiation

- Blackbody: emits based on its temperature; absorbs all light incident on it.
- Spectral Irradiance for black body:
  – Depend on temperature of blackbody source
  – ↑T -» ↑ power density, shifts spectrum more to blue

$$S_\lambda = \frac{2\pi c^2 h}{\lambda^5} \frac{\alpha(\lambda)}{e^{hc/\lambda kT} - 1}$$

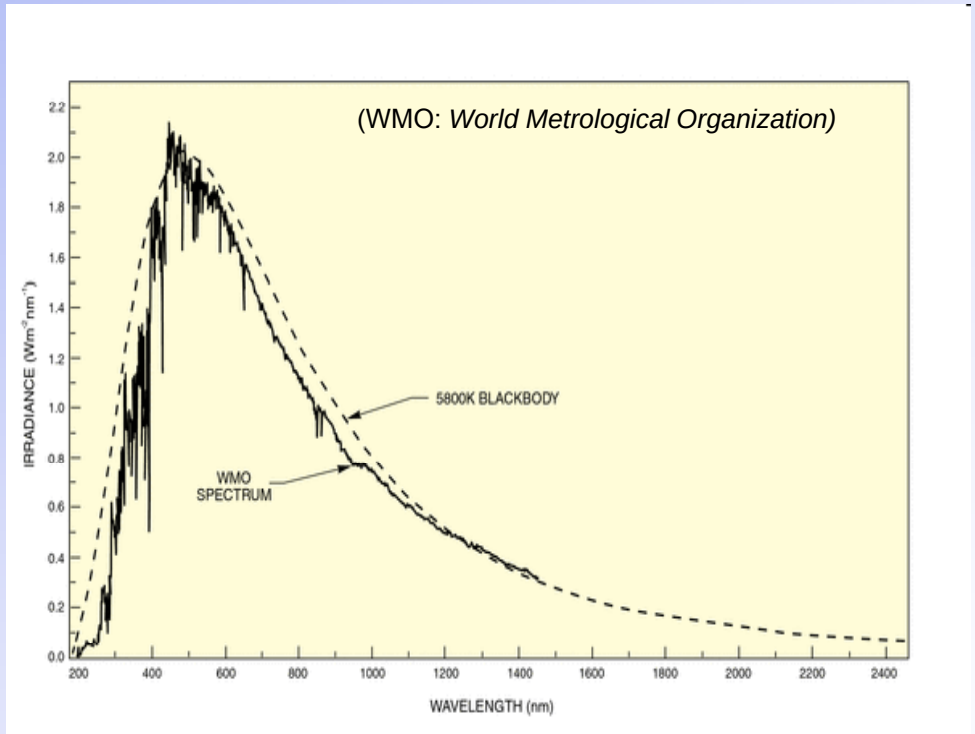
☞ Sun approximates a black body at ~5800 K, radiating with a power density of $H_{sun} \approx 73$ MW/m².



http://www.rumford.com/radiant/images/Wiengraph.gif

The Solar Radiation

- The energy flow within the sun results in a surface temperature of around 5800 K, so the spectrum of the radiation from the sun is similar to that of a 5800 K blackbody
- The irradiance of the sun on the outer atmosphere when the sun and earth are spaced at 1 AU - the mean earth/sun distance of 149,597,890 km - is called the **solar constant**
- Currently accepted values are about **1360** W m^{-2}
- It covers the spectrum from ultraviolet, through visible, to near infrared wavelengths



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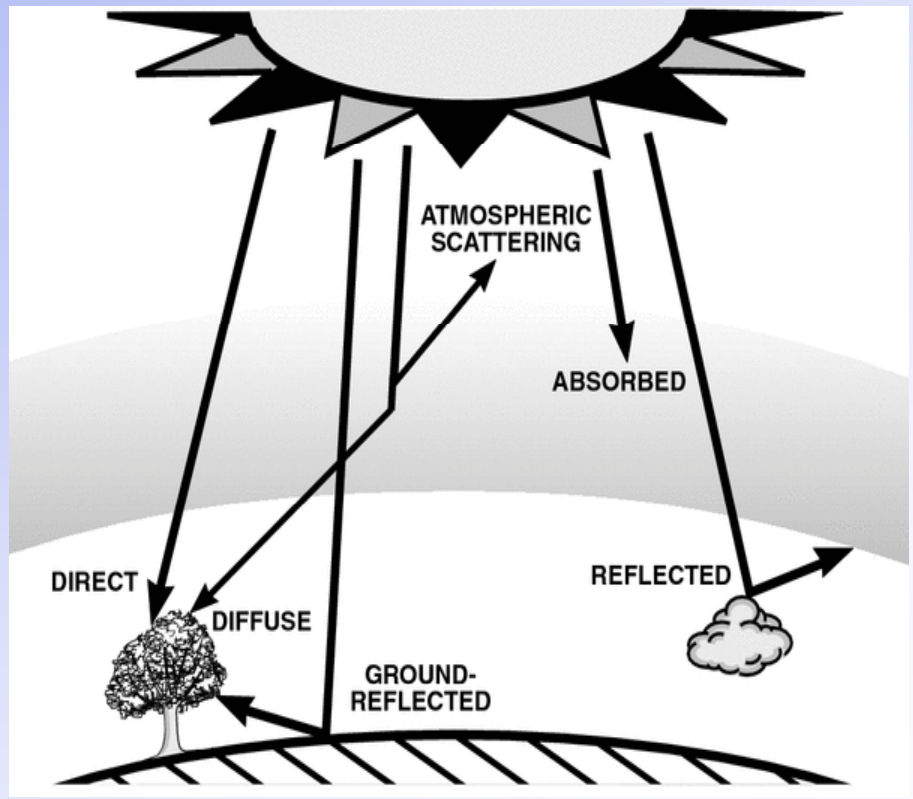
The Solar Radiation

- **Atmospheric Effects:** Solar radiation is absorbed, scattered and reflected by components of the atmosphere
- The amount of radiation reaching the earth is less than what entered the top of the atmosphere. We classify it in two categories:
  1. ***Direct Radiation*:** radiation from the sun that reaches the earth without scattering
  2. ***Diffuse Radiation*:** radiation that is scattered by the atmosphere and clouds



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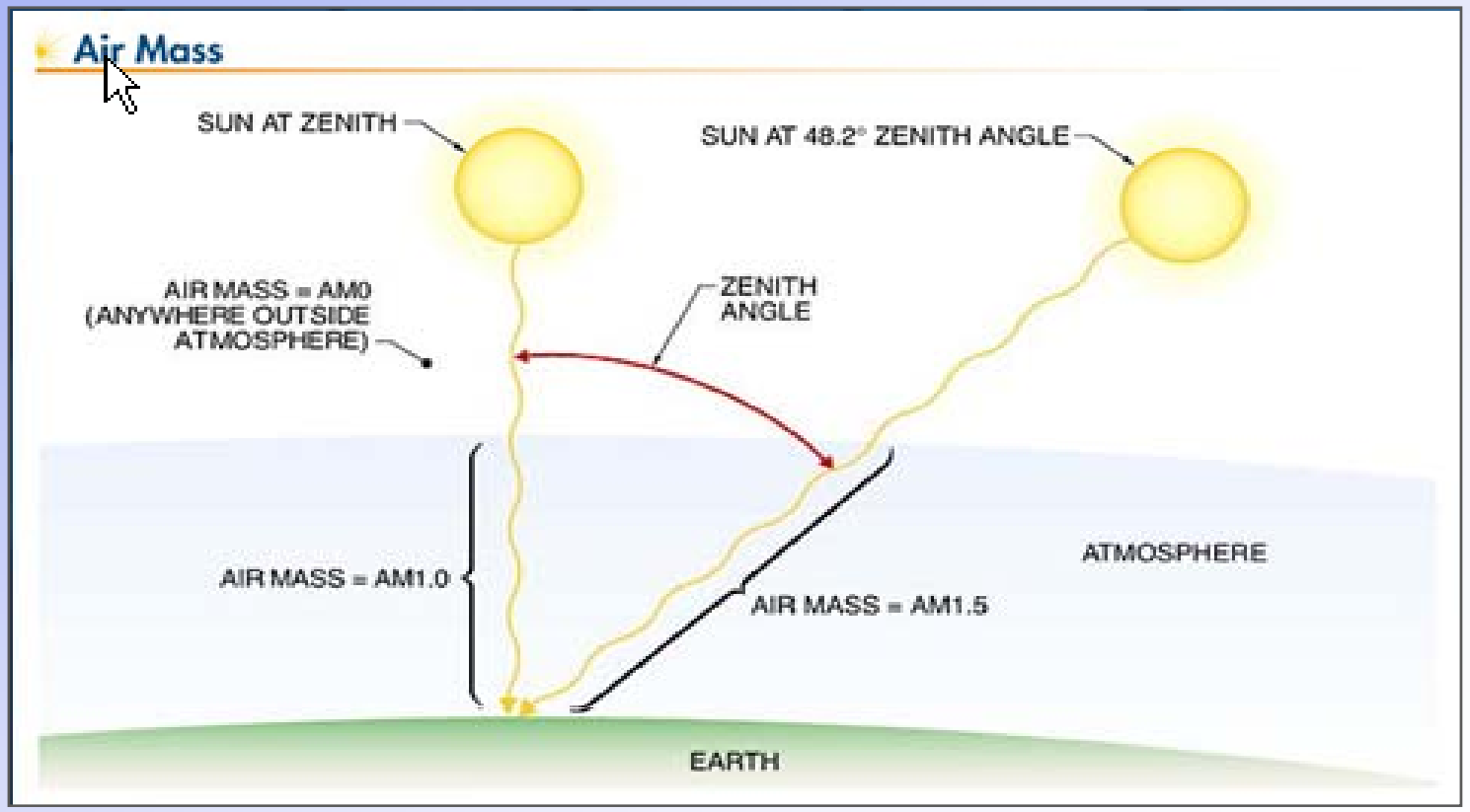
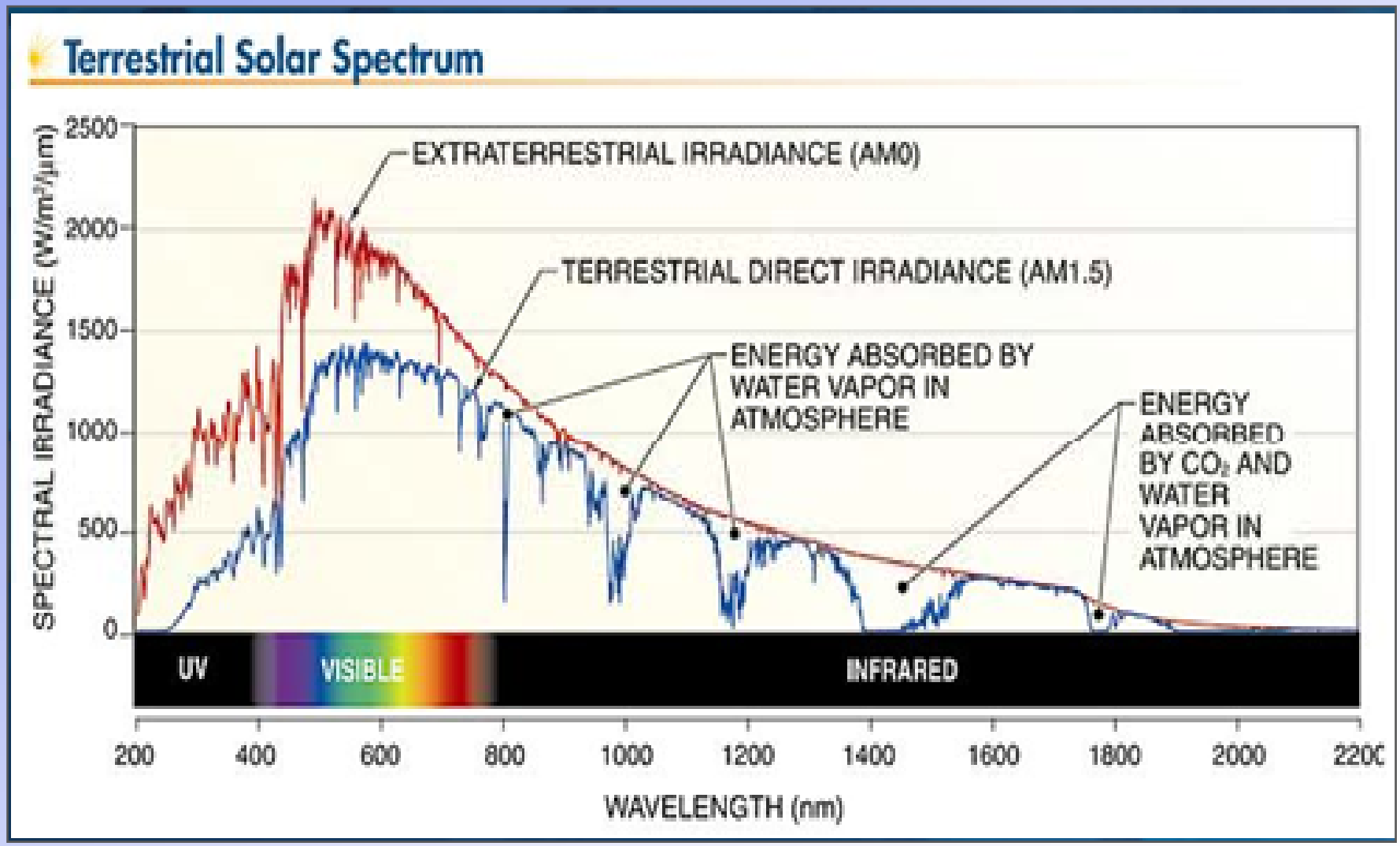
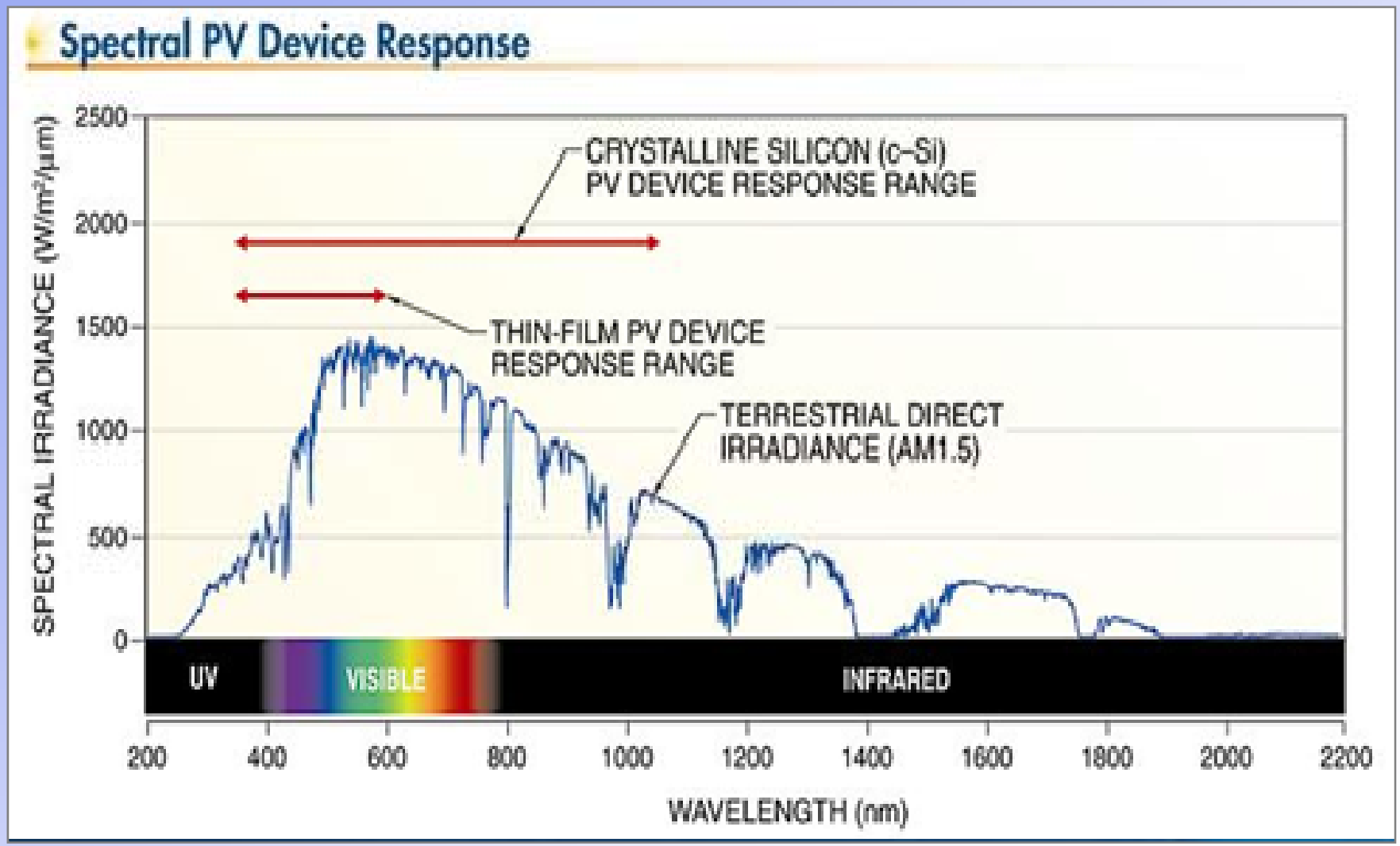
- **Air Mass** represents how much atmosphere the solar radiation has to pass through before reaching the Earth's surface
- Air Mass (AM) equals 1.0 when the sun is directly overhead at sea level. AM = 1/ Cos Θ_z
- We are specifically concerned with terrestrial solar radiation –that is, the solar radiation reaching the surface of the earth.



Extraterrestrial and Terrestrial Spectra



www.cabrillo.edu/.../Chapter%202%20Solar%20Radiation



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Standard Spectra

• Solar radiation reaching the earth's surface varies significantly with location, atmospheric conditions including cloud cover, aerosol content, and ozone layer condition, and time of day, earth/sun distance, solar rotation and activity

• Standard spectra have been developed to provide a basis for theoretical evaluation of the effects of solar radiation and as a basis for simulator design

• The most widely used standard spectra are those published by The Committee Internationale d'Eclaraige (CIE), the world authority on radiometeric and photometric nomenclature and standards

• The American Society for Testing and Materials (ASTM) publish three spectra - the AM 0, AM 1.5 Direct and AM 1.5 Global for a 37° tilted surface

Standard Spectra

Solar Condition	Standard	Power Density (Wm^{-2})		
		Total	250 - 2500 nm	250 - 1100 nm
	WMO Spectrum	1367		
AM 0	ASTM E 490	1353	1302.6	1006.9
AM 1	CIE Publication 85, Table 2		969.7	779.4
AM 1.5 D	ASTM E 891	768.3	756.5	584.7
AM 1.5 G	ASTM E 892	963.8	951.5	768.6
AM 1.5 G	CEI/IEC* 904-3	1000	987.2	797.5

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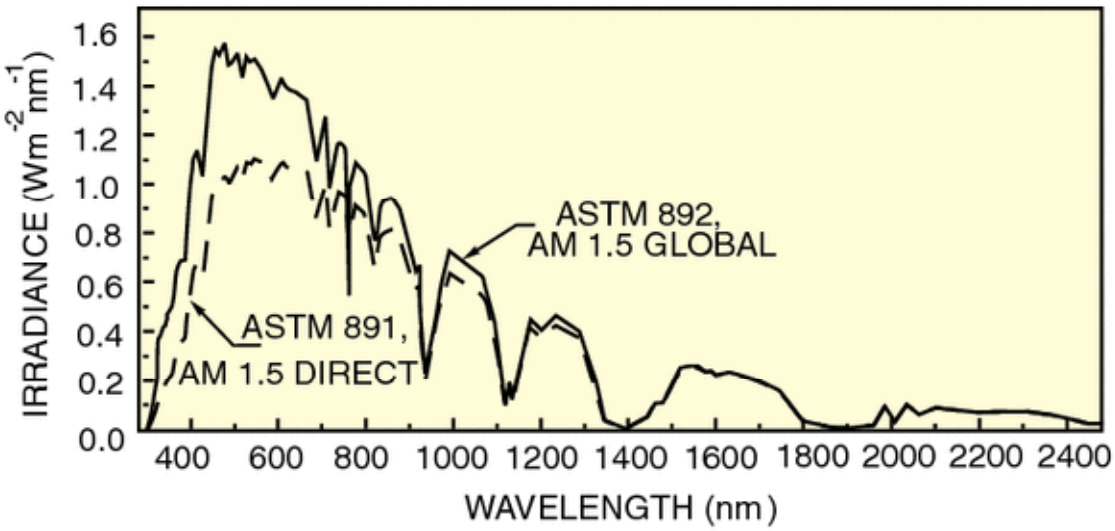


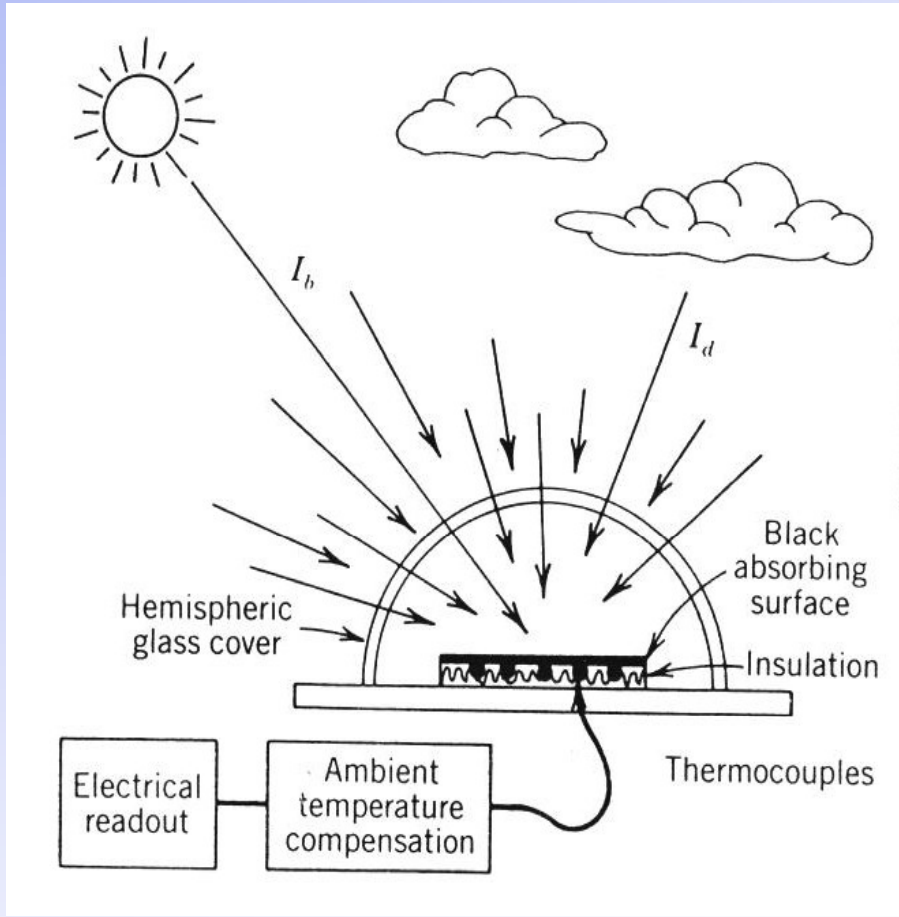
Measurement of Solar Irradiation

- The primary instrument used to measure global solar irradiance is the ***pyranometer***, which measures the sun's energy coming from all directions in the hemisphere above the plane of the instrument
- The measurement is of the sum of the direct and the diffuse solar irradiance and is called the ***global solar irradiance***

Horizontal and tilted pyranometer (left, courtesy skytron energy)
Pyranometer CMP11 (right, courtesy: Kipp & Zonen)

Measurement of Solar Irradiation

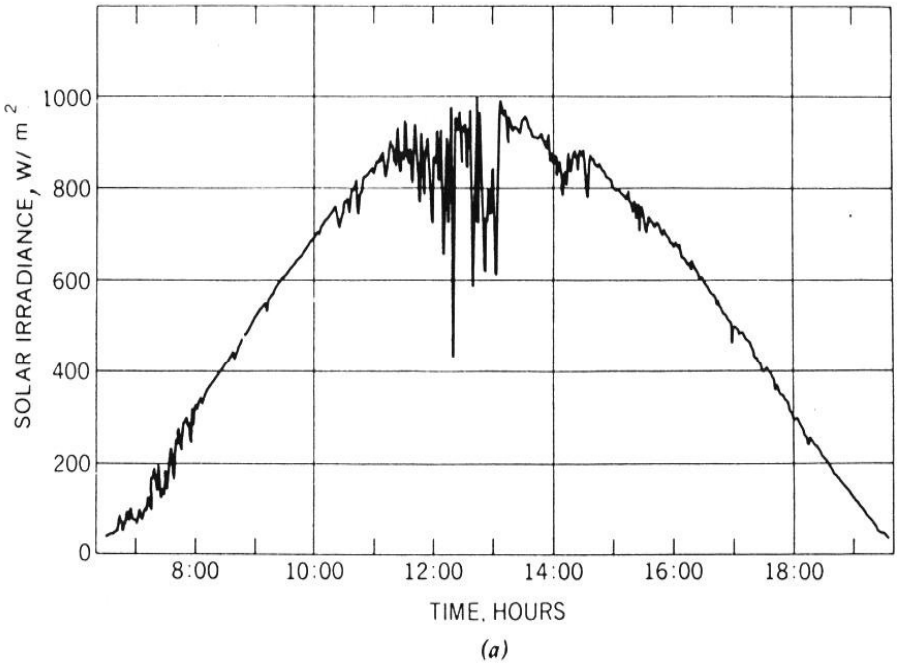
- The most common pyranometer design uses a ***thermopile*** (multiple thermocouples connected in series) attached to a thin blackened absorbing surface shielded from convective loss and insulated against conductive losses
- When placed in the sun, the surface attains a temperature proportional to the amount of radiant energy falling on it. The temperature is measured and converted through accurate calibration into a readout of the global solar irradiance falling on the absorbing surface

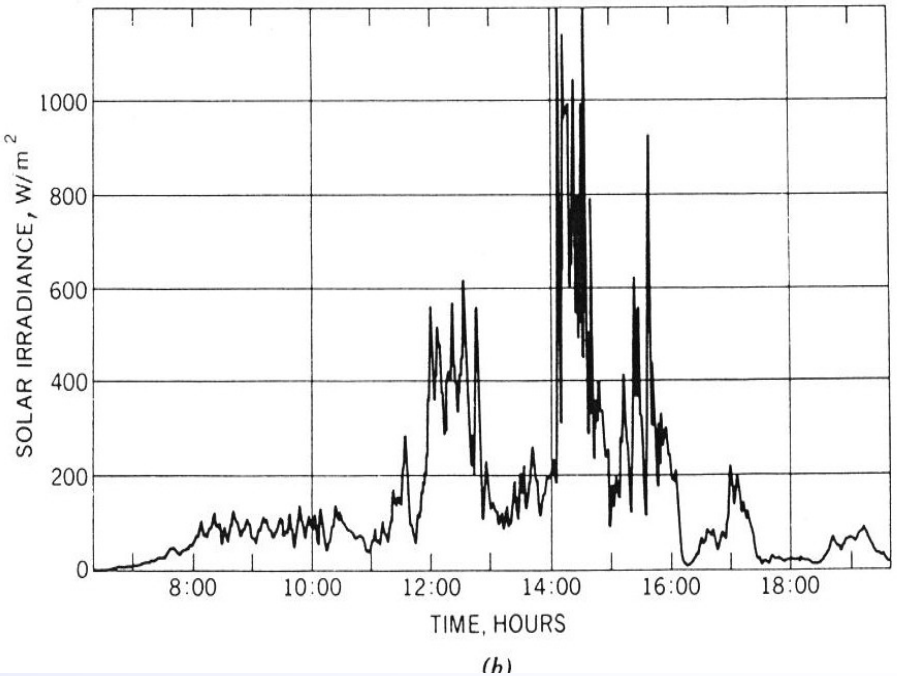


Photos courtesy of the Eppley Laboratory, Inc.

Measurement of Solar Irradiation

• Example of global (total) irradiance on a horizontal surface for a mostly clear day and a mostly cloudy day in Greenbelt, MD (Thekaekara, 1976): (a) global solar radiation for the day was 27.1 MJ/m^2; (b) global solar radiation for the day was 7.3 MJ/m^2.

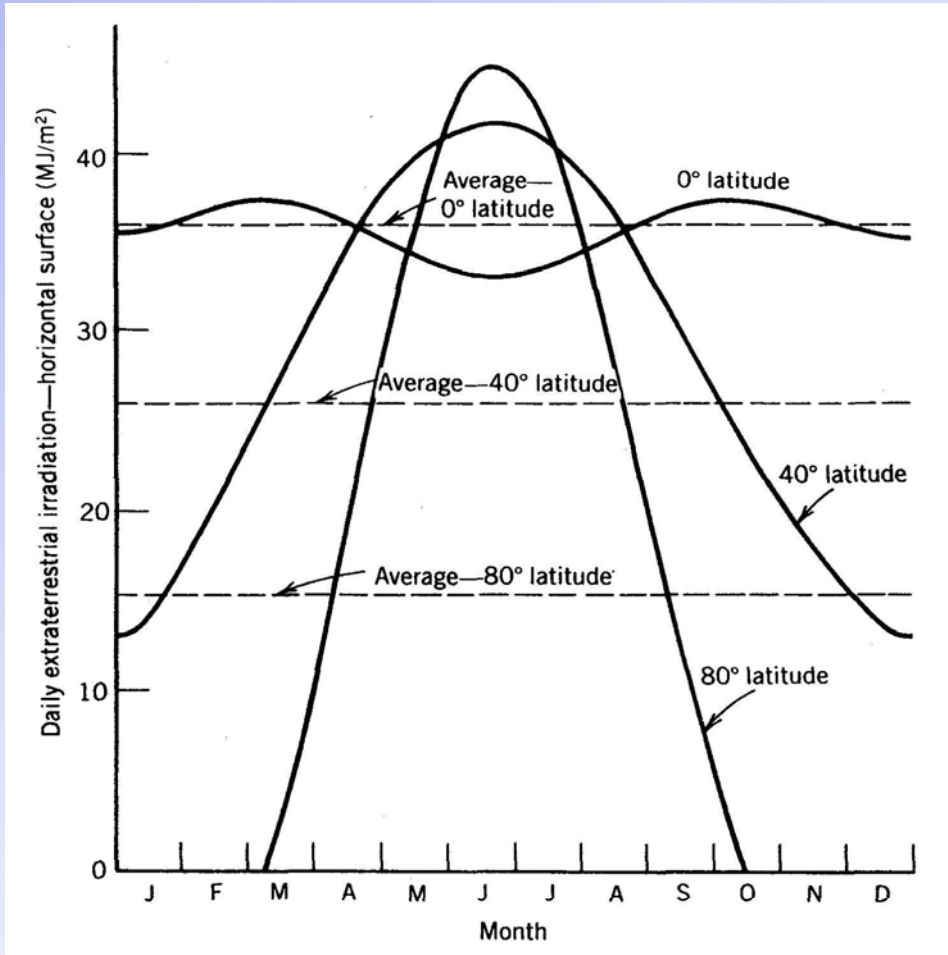




http://www.powerfromthesun.net/Book/chapter02/chapter02.html

Measurement of Solar Irradiation

• Seasonal variation of the daily extraterrestrial solar radiation (irradiation) incident on a horizontal surface outside the earth's atmosphere in the northern hemisphere strongly depends on the latitude



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Thank you for your attention !