

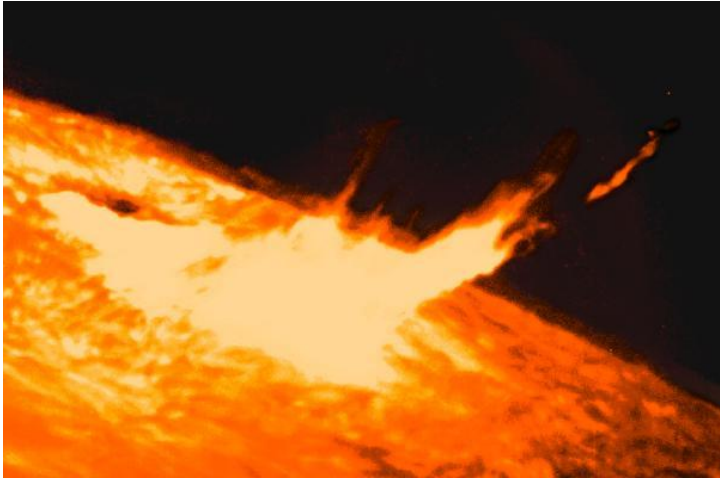
وزارة الطيران المدني
الهيئة العامة للأرصاد الجوية
الإدارة المركزية لبحوث الأرصاد الجوية
مركز القاهرة الأقليمي للأشعاع

قياسات الأشعاع الشمسي

الأستاذ / مجدي السيد الصادق معمل الأشعاع الشمسي

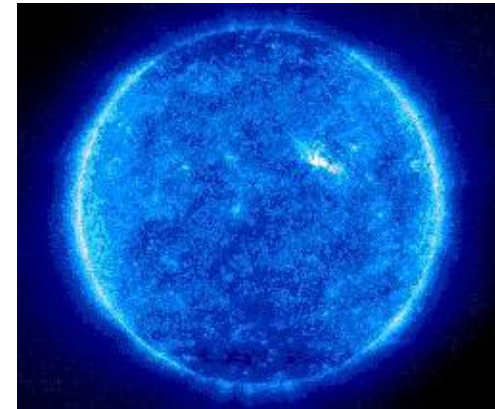
WHAT IS SOLAR RADIATION?

SOLAR RADIATION



Solar flare image (SOLIS project). The sun's surface temperature is about 5700 Kelvin.

The Sun at UV wavelengths.
(Solar and Heliospheric Observatory project)



SOLAR RADIATION

HOW MUCH SOLAR ENERGY IS OUT THERE ?

- The energy emitted by the sun is about 3.72×10^{26} MW
- Radiative power is approximately 63 MW per m^2 of its surface
- The mean distance from Sun to Earth is about 150 million km (1 astronomical unit, 1 AU)
- The Direct Normal Irradiance (DNI) at the top of the Earth's atmosphere is the 'Solar Constant'
- The Solar Constant is $1,360.8 \pm 0.5 \text{ W/m}^2$ (NASA, 2008)
- It varies 0.1% due to sun activity cycles (nominally 11 years)
- It is 6.6% higher in January (Perihelion) than July (Aphelion)

SOLAR RADIATION

THE SOLAR SPECTRUM

Spectral range of solar radiation



UVC
UVB
UVA

VISIBLE

NEAR - INFRARED

Wavelength Intervals (1 nm = 10⁻⁹ m)

... 280 nm

280-315 nm

315-400 nm

400- 780 nm

780-4000 nm

UVC

UVB

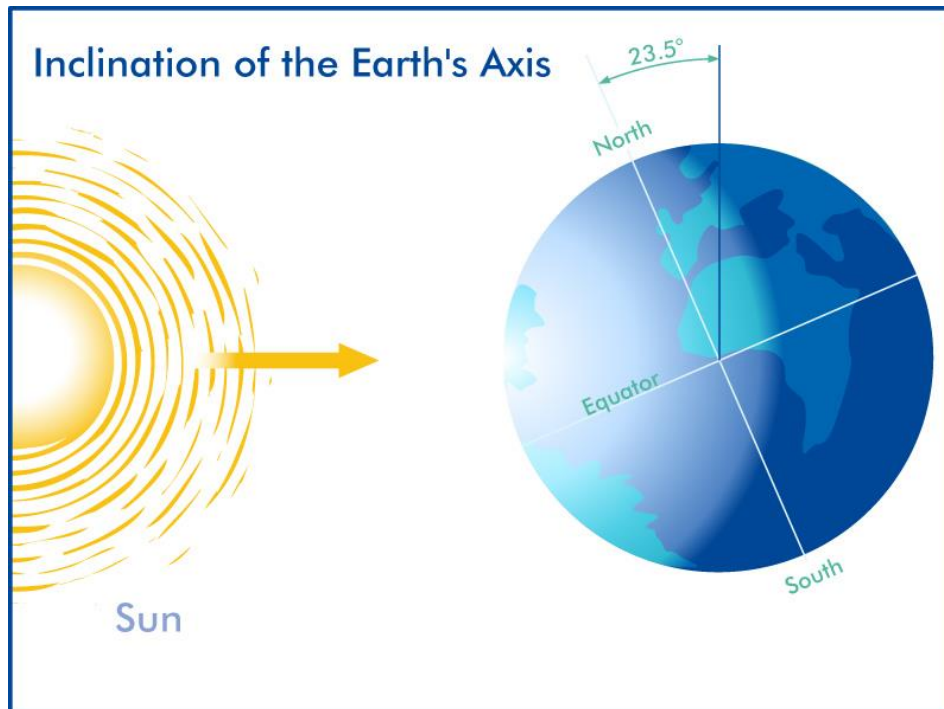
UVA

Visible

Near Infrared

SOLAR RADIATION

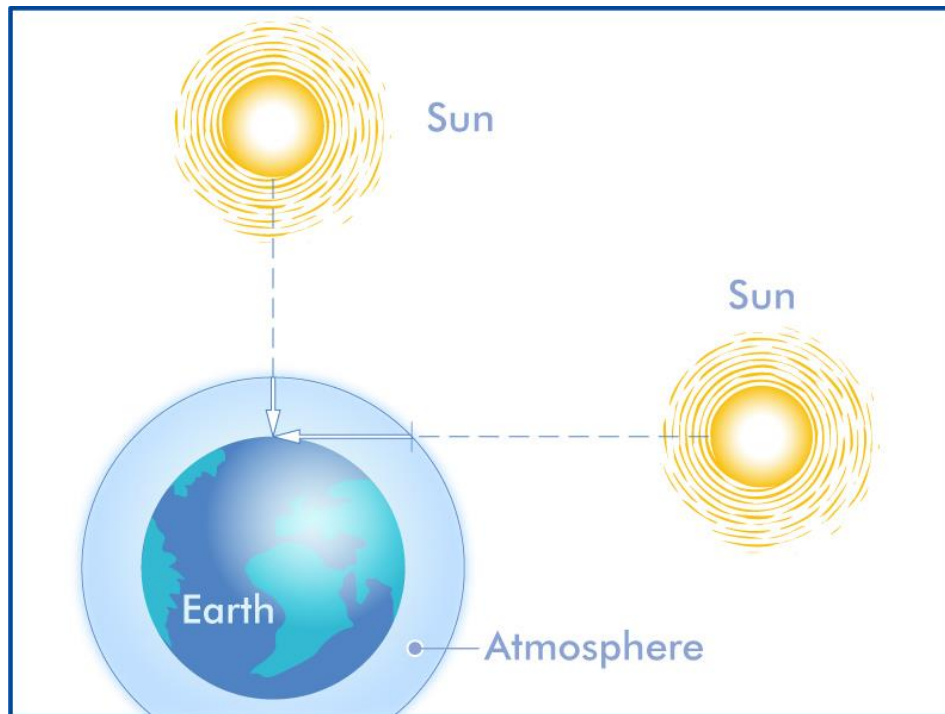
WHAT AFFECTS ENERGY REACHING THE GROUND ?



- Location
- Time and date
- Clouds
- Aerosols
- Pollution
- Atmosphere
- Reflection
- Absorption
- Scattering

SOLAR RADIATION

WHAT IS AIR MASS ?



Air Mass = $1/\text{Cos } \theta$
(Solar Zenith Angle)

Sun at Solar Zenith
Angle of 0°
AM = 1

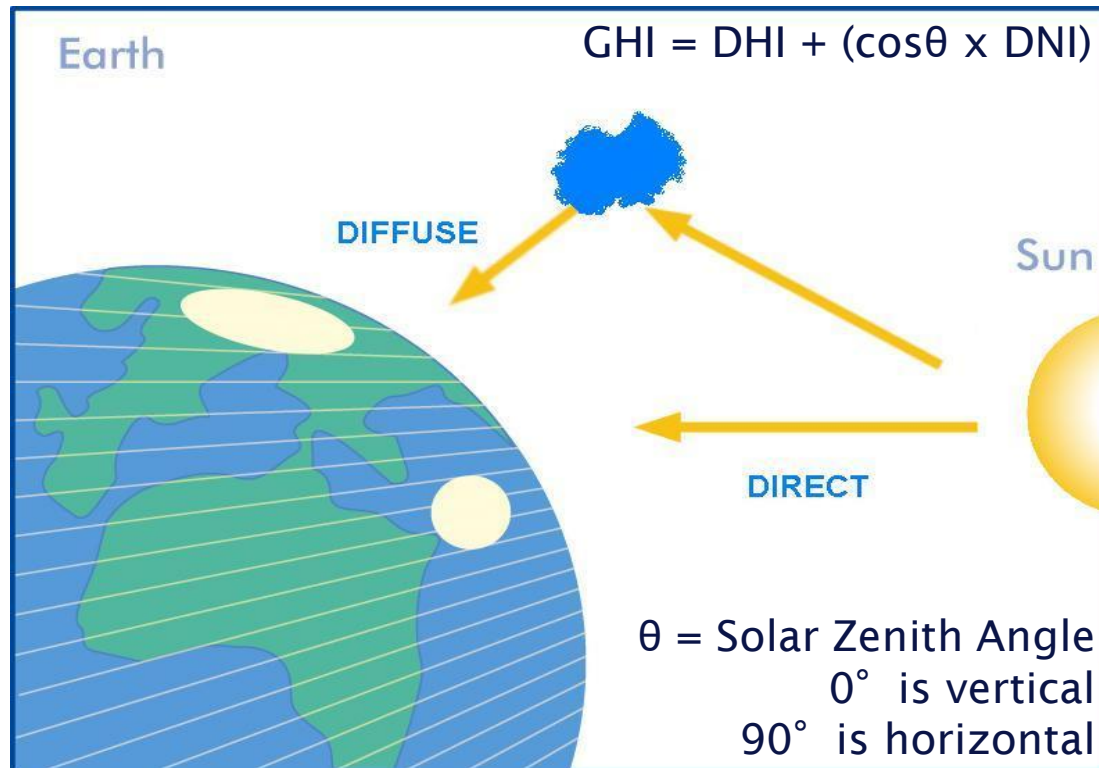
Sun at Solar Zenith
Angle of 48.2°
AM = 1.5

Relationship breaks
down beyond Solar
Zenith Angle of 85°
AM = 11.4

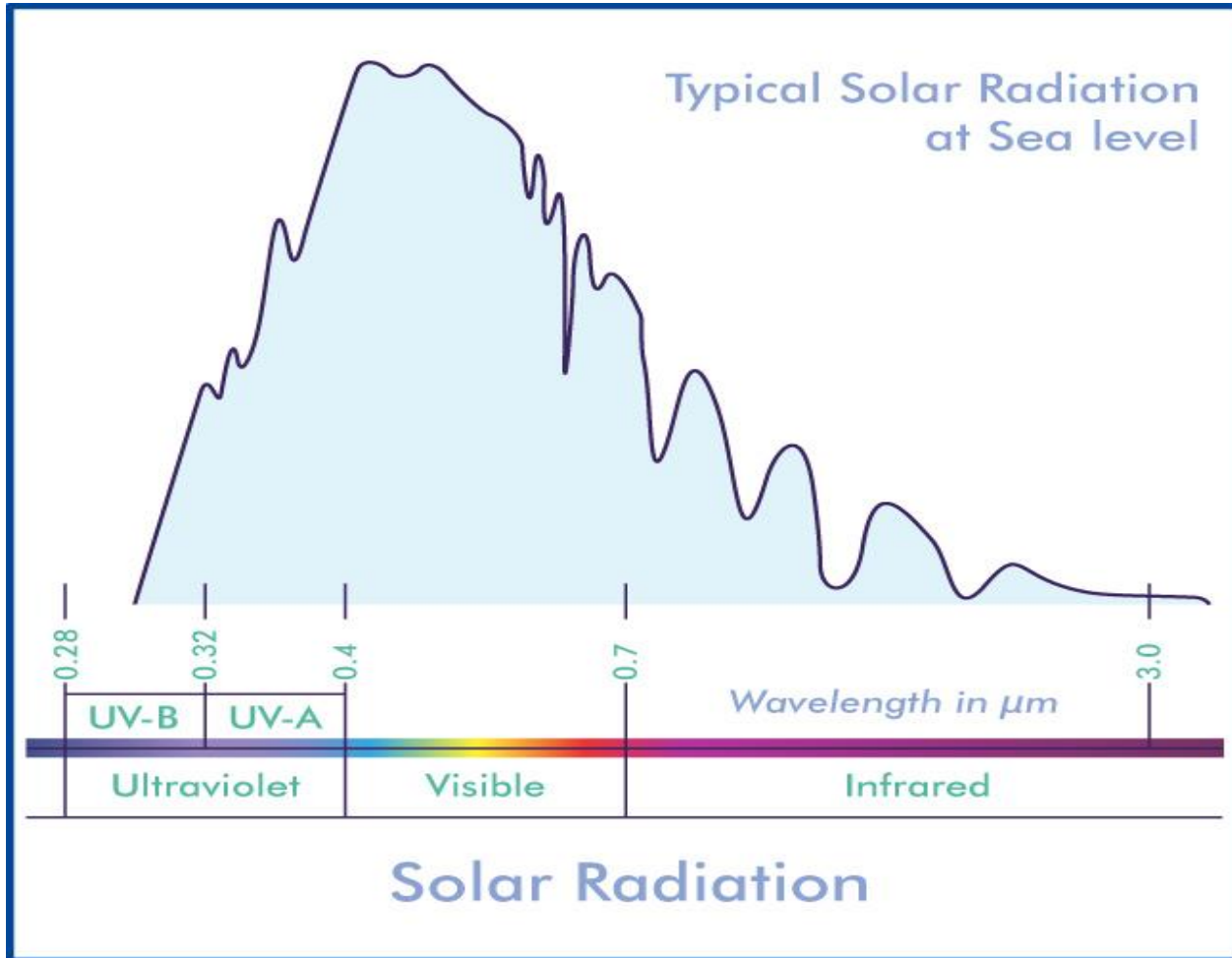
SOLAR RADIATION

THE COMPONENTS OF SOLAR RADIATION

Direct Normal Irradiance - DNI; Diffuse Horizontal Irradiance - DHI
Global Horizontal Irradiance - GHI. All are measured in W/m^2 .

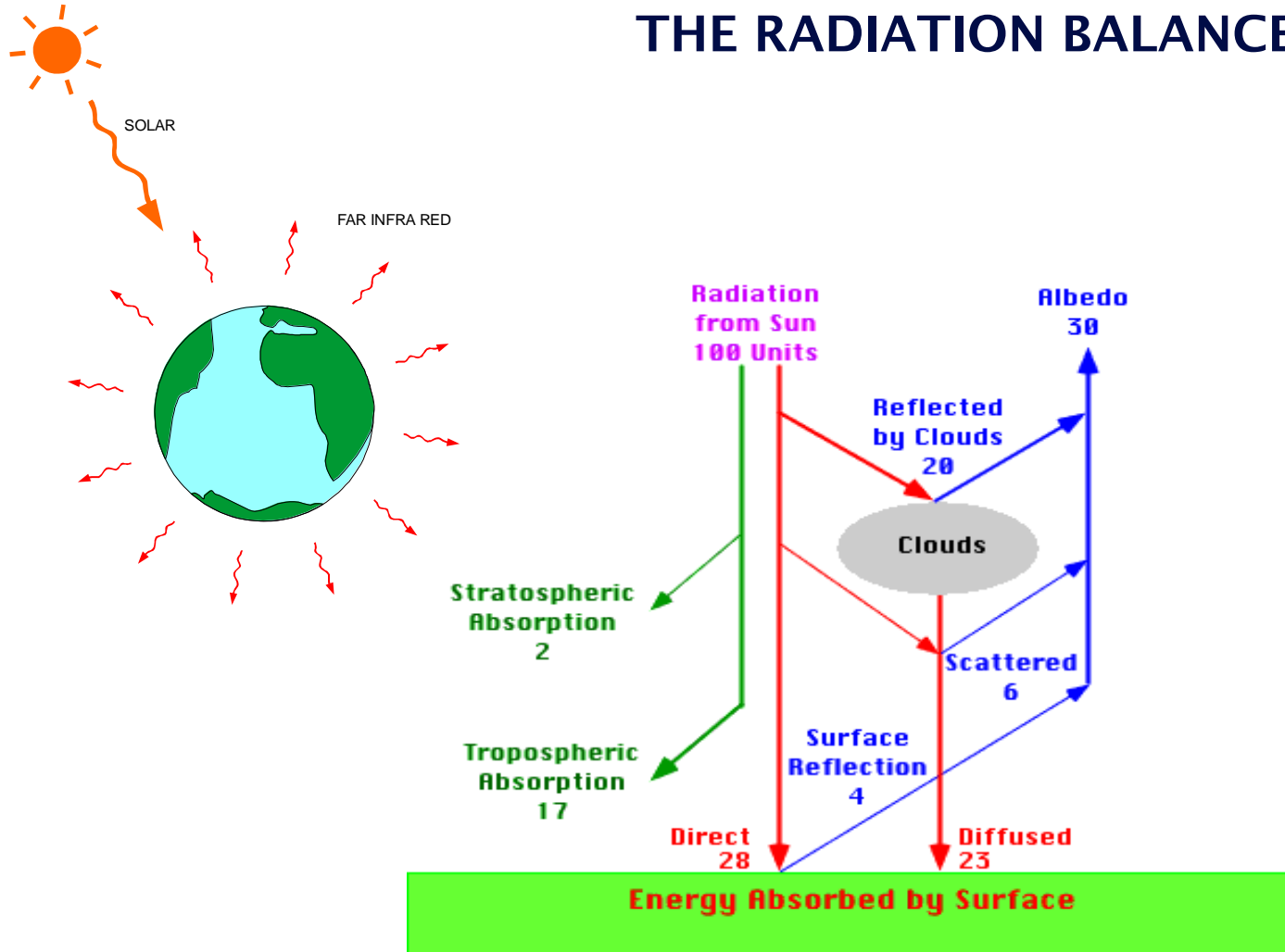


SOLAR RADIATION



SOLAR RADIATION

THE RADIATION BALANCE



SOLAR RADIATION

RADIOMETER TYPES



< 280 nm

280-315 nm

315-400 nm

400-780 nm

780-4000 nm

4-50 μm

UV-C

UV-B

UV-A

Visible

Near Infrared

Far Infrared



SOLAR RADIATION

WHY MAKE HIGH QUALITY MEASUREMENTS ?

Solar energy resource data bases are largely based upon:

- Satellite measurements
- Information from meteorological networks
- Models

However, often:

- Spatial resolution is not good enough
- Satellites measurements may have low temporal resolution and might not be locally validated (ground-truthed)
- Meteorological pyranometers may have relatively poor accuracy

These data are not good enough to make investment decisions.

SOLAR RADIATION

WHY MAKE HIGH QUALITY MEASUREMENTS ?

The actual available energy at prospective solar power generation locations needs to be measured on-site over a full year.

Accurate measurements are essential to make meaningful decisions on locations for solar energy power plants and to choose the most appropriate technology for that location.

Errors in the estimates of available solar radiation can significantly impact upon the return on investment.

Investors generally require an uncertainty in the solar radiation resource assessment in the order of 2% for decision making.

Performance ratio/efficiency calculations also require an uncertainty of around 2% in developed markets.

This is achievable with high quality equipment currently available.

شبكة الاشعاع على جمهورية مصر العربية

Regional Radiation Centres (RRC)

Region I (Africa)

- Cairo (Egypt)
- Khartoum (Sudan)
- Kinshasa (Dem. Rep. of the Congo)
- Lagos (Nigeria)
- Tamanrasset (Algeria)
- Tunis (Tunisia)

Region II (Asia)

- Pune (India)
- Tokyo (Japan)

Region III (South America)

- Buenos Aires (Argentina)
- Lima (Peru)
- Santiago (Chile)

Region IV (North and Central America)

- Toronto (Canada)
- Boulder (United States)
- Mexico City (Mexico)

Region V (South-West Pacific)

- Melbourne (Australia)

Region VI (Europe)

- Budapest (Hungary)
- Davos (Switzerland)
- St. Petersburg (Russian Federation)
- Norrköping (Sweden)
- Trappes/Carpentras (France)
- Uccle (Belgium)
- Lindenberg (Germany)

A Regional Radiation Centre is a centre designated by a Regional Association to serve as a centre for interregional comparisons of radiation instruments within the Region and to maintain the standard instruments necessary for this purpose.

Regional Radiation Centres shall satisfy the following conditions before it is designated as such and shall continue to fulfil them after being designated:

1. It shall possess and maintain a standard group of at least three stable pyrheliometers, with a traceable 95% uncertainty of less than 1 Wm^{-2} to the World Standard Group, and in stable clear sun conditions with direct irradiances above 700 Wm^{-2} , 95% of any single measurements of



