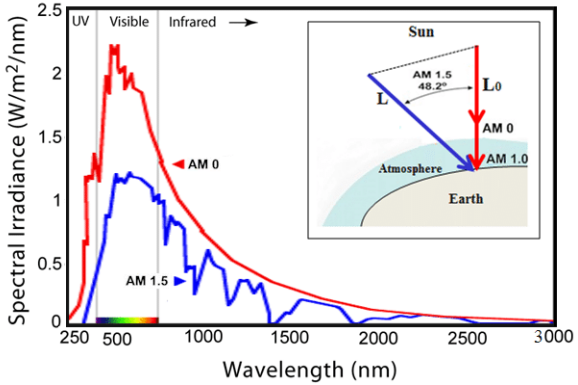
EN 671 Solar Energy Conversion and Technology

Lecture -4: Solar Radiation Geometry

Dr. Pankaj Kalita
Associate Professor, School of Energy Science and Engineering
Indian Institute of Technology, Guwahati

Summary of the last lecture

- Propagation of solar radiation from the surface of the Sun to the earth's surface.
- Atmospheric absorption and scattering.
- Sun-earth relationship.
- Different types of radiation .
- Air mass (AM0, AM1, AM2, AM1.5).



Monthly variation of solar radiation flux in the extra-terrestrial region

$$I_{ext} = I_{sc}\left[1.0 + 0.033\cos\left(360n/365\right)\right]$$

✓ Solar Radiation and sunshine Measuring Instruments

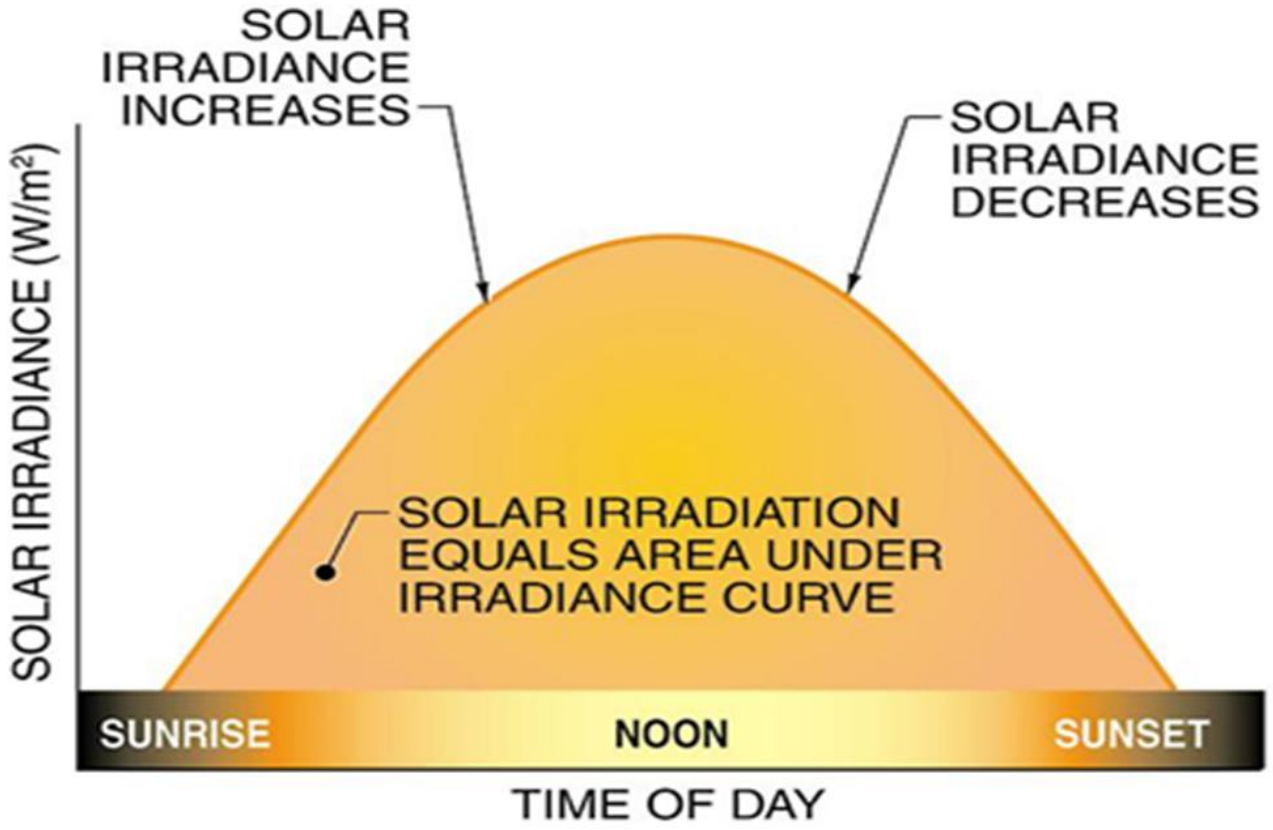
Concern of Solar Energy Conversion

- Make measurements over a period of time.
- Use the available data for some other location having reasonably similar climatic condition.
- Use empirical predictive equations.

Atmosphere at earth's surface

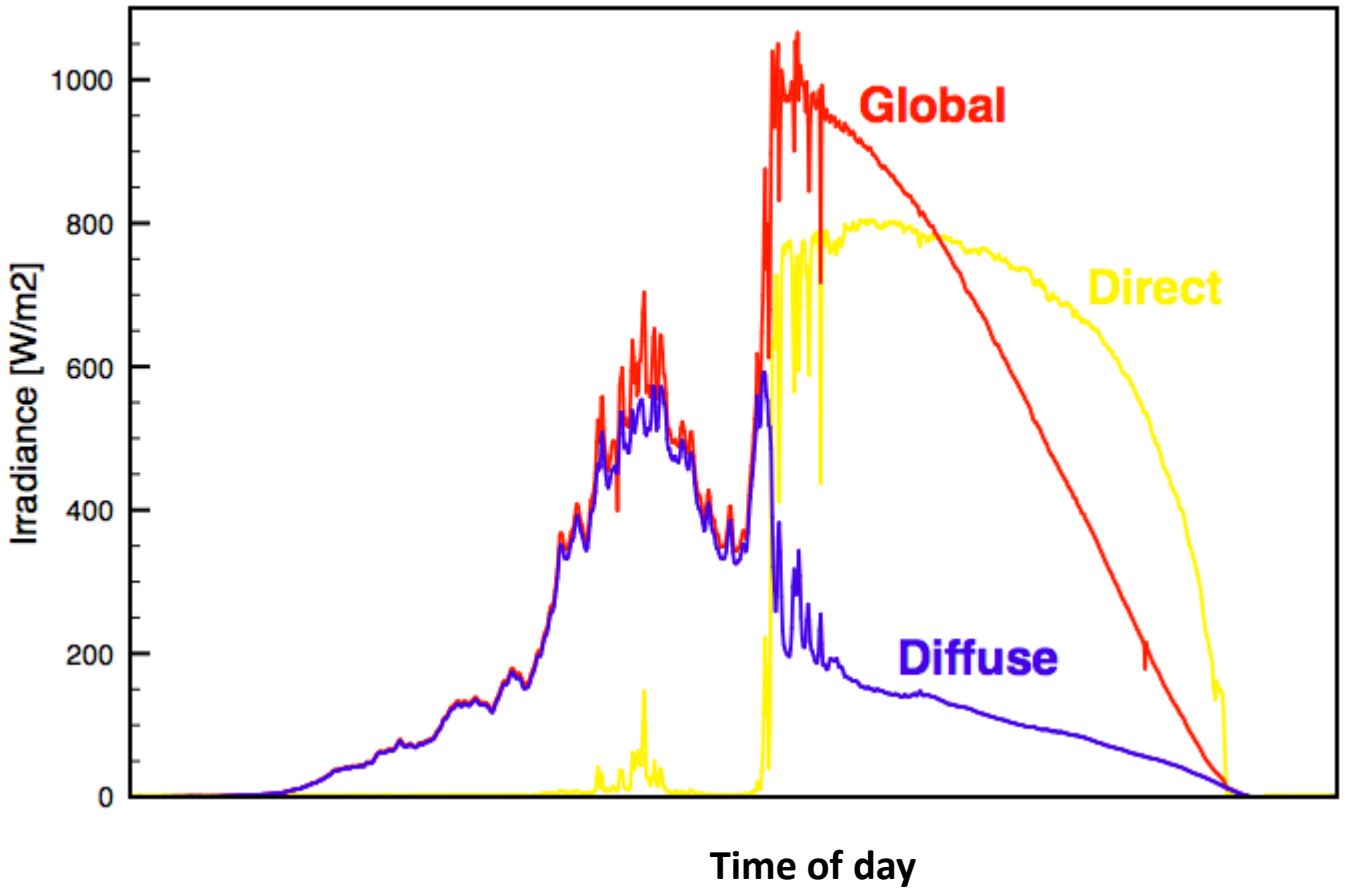
- An atmosphere without clouds (Cloud less)
- An atmosphere with clouds (partially or fully covered by cloud)

Solar Radiation received on a Clear Sky



Solar Irradiance and Irradiation

Solar Radiation received on a partially cloudy sky

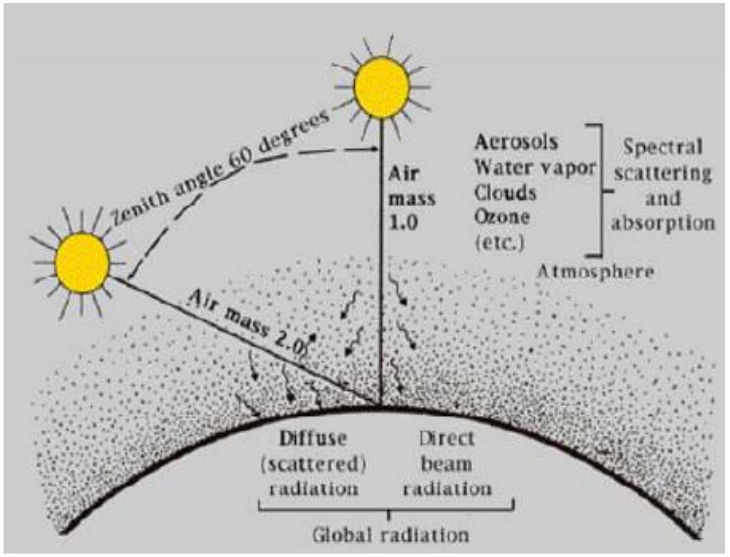


Types of solar radiation

1. Direct radiation ***(beam radiation or direct beam radiation)***: Describes solar radiation traveling on a straight line from the sun down to the surface of the earth.

2. Diffuse radiation: Describes the sunlight that has been scattered by molecules and particles in the atmosphere but that has still made it down to the surface of the earth.

3. Reflected radiation: Describes sunlight that has been reflected off of non-atmospheric things such as the ground. **Asphalt reflects about 4% of the light that strikes it and a lawn about 25%.**



SOLAR INSTRUMENTS

- PYRANOMETERS
- PYRHELIOMETERS
- SUNSHINE RECORDER

Direct Normal

Measured by a *Pyrheliometer* on a sun-following tracker

Global Horizontal

Measured by a *Pyranometer* with a horizontal sensor

Diffuse

Measured by a shaded *Pyranometer* under a tracking ball

PYRANOMETERS

Used to measure **global** and **diffuse** solar radiation

Application

- Material testing research, and assessment of the efficiency of solar collectors and photovoltaic devices.

PYRHELIOMETER

- **Used to measure beam solar irradiance.**
- **Sunlight enters the instrument through a window and is directed on thermopile which converts heat to an electrical signal that can be recorded. The signal voltage is converted via a formula to measure watts per square meter.**
- **It is used with a solar tracking system to keep the instrument aimed at the sun.**

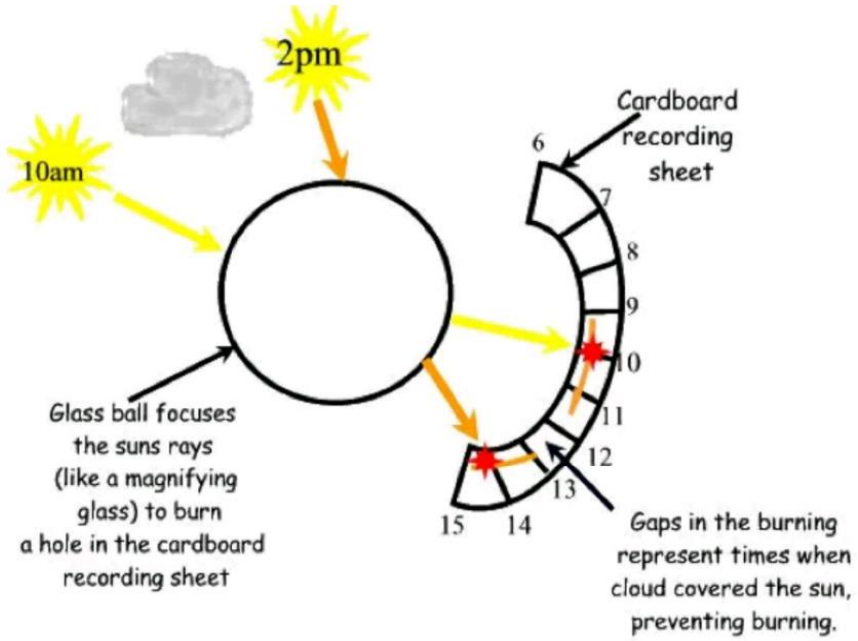
Components: Protection cap, Sensor, Thermopile

Application

- Meteorology, material testing research, and assessment of the efficiency of solar collectors and photovoltaic devices.

SUNSHINE RECORDER

- A device that records the amount of sunshine duration at a given location
- The most commonly used is CAMPBELL-STOKES recorder
- A burnt trace whose length is proportional to the duration of sunshine is obtained on the strip



SENSORS

HEAT FLUX SENSOR

A **heat flux sensor** is a transducer that generates an electrical signal proportional to the total heat rate applied to the surface of the sensor.

SUNSHINE DURATION SENSOR

Sunshine duration is defined as the time during which the direct solar radiation exceeds the level of 120 W/m².

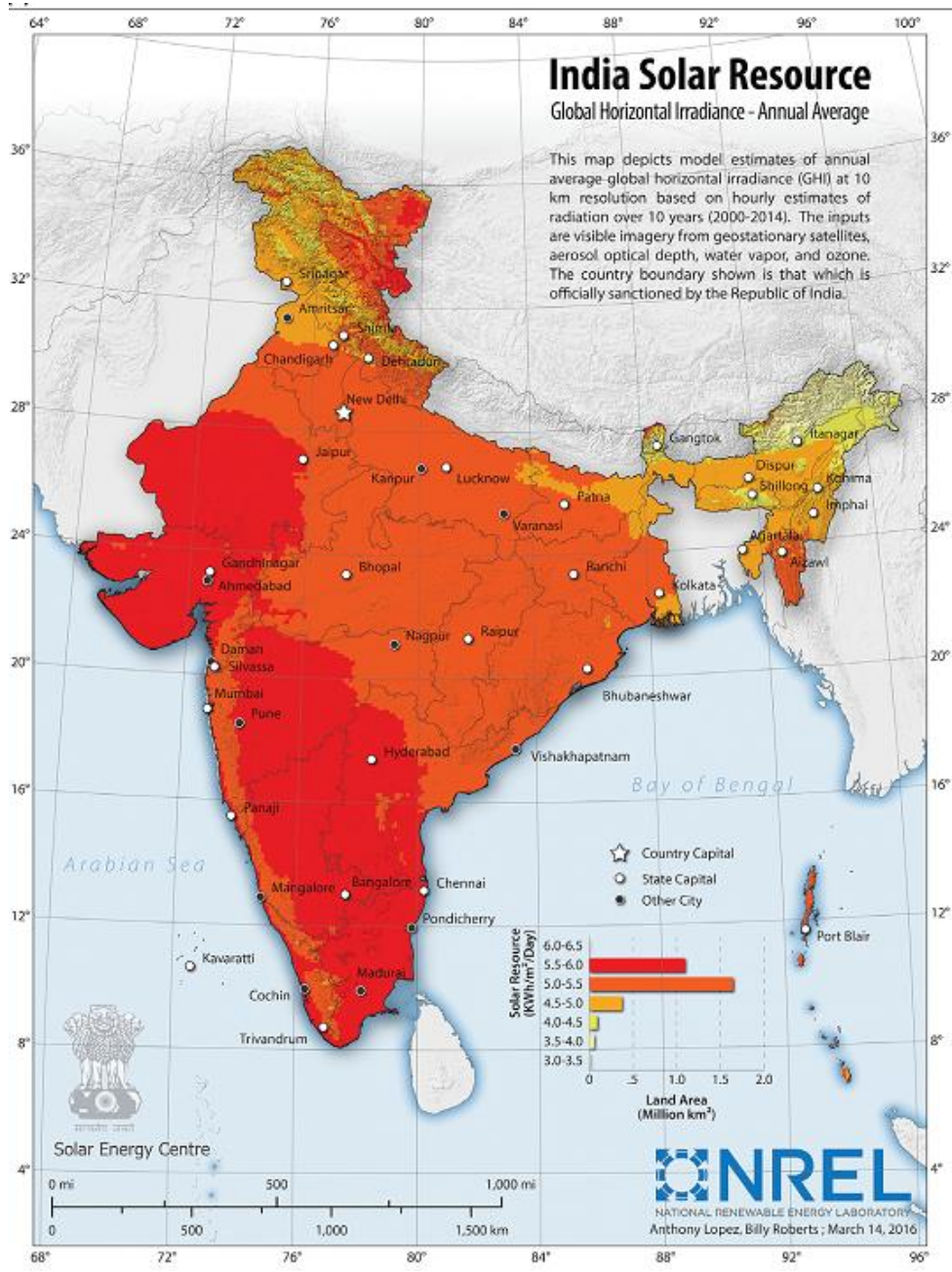
Thermopile Detectors

Pyrheliometer

Pyranometer

Solar radiation data

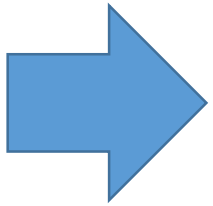
- Solar radiation flux is sometimes represented in langleys per hour or per day (1 langley = 1 cal/cm^2=1.163 x 10^{-2} kWh/m^2)
- Samuel Langley who made the first measurement of the spectral distribution of the Sun.
- **Annual average global radiation** received = 450 langleys per day (peak – 600 langleys per day on Rajasthan and Gujarat) - in Winter and monsoon: 300-400 langleys per day.
- Annual average diffuse radiation received = 175 langleys per day, maximum: 300 in July and 75-100 langleys per day in Nov and Dec



Solar radiation data

- Instantaneous Global and Diffuse flux (W/m^2)
- Hourly values of Global and Diffuse flux (kWh/m^2-h or kJ/m^2-h)
- For daily global and diffuse flux incident over a whole day (in kWh/m^2-day or kJ/m^2-day)

What Influences the solar radiation?



- Earth-Sun Distance
- Relative tilt
- Time of the day

Irradiance (W/m^2): **The rate at which radiant energy is incident on a surface per unit area of surface.**

Irradiation (J/m^2): **The incident energy per unit area on a surface found by integration of irradiance over a specified time, usually an hour or a day.**

Insolation: **Apply specifically to solar energy irradiation.**

Summary

- Concerns of solar equipment designer
- Different instruments used for radiation measurement
- Units of radiation
- Radiation data

Thank you