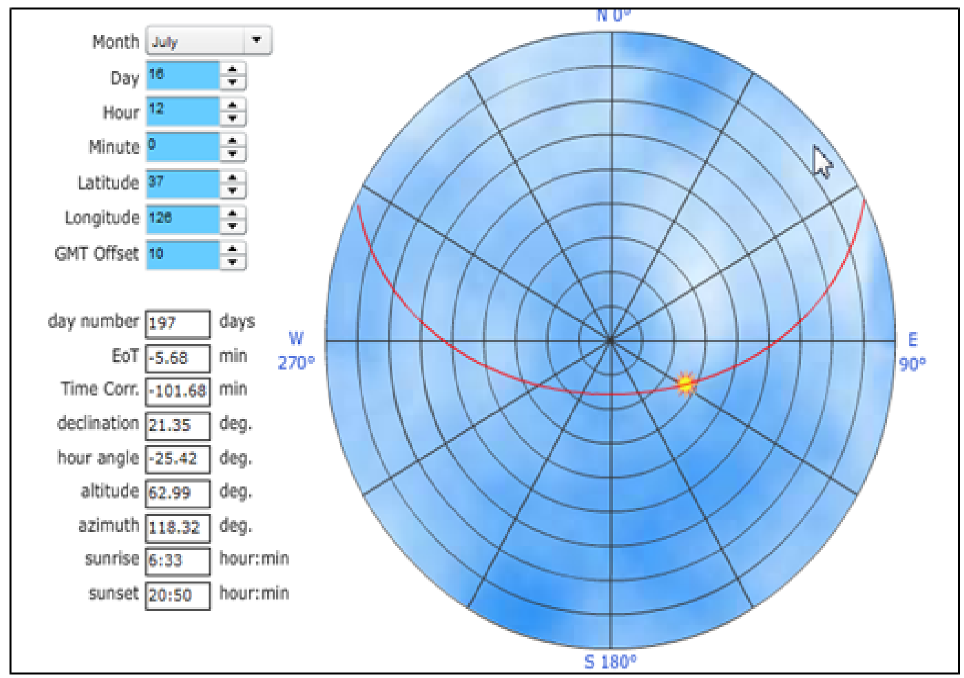
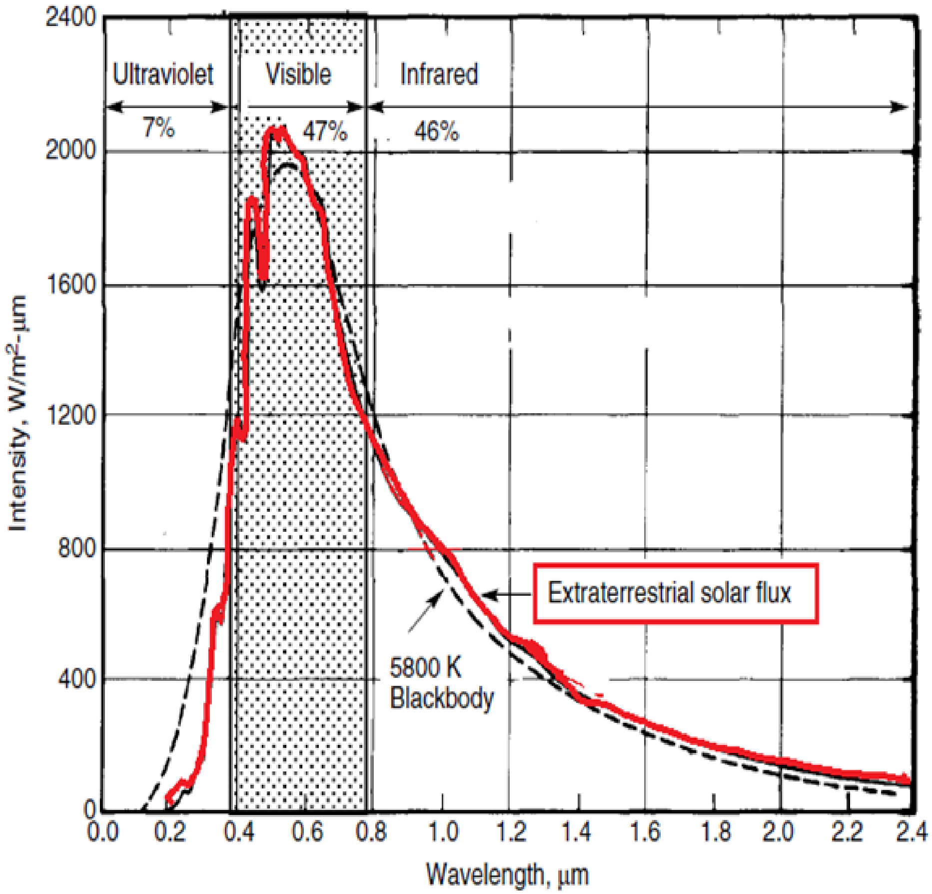
Chapter 7. Solar Resource


⌘ What do we have to know to design a solar system?

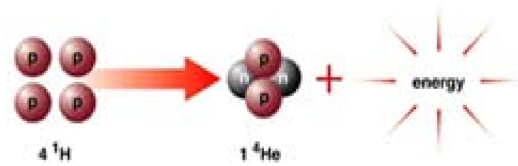
- How much sunlight is available?
- Where is the sun in the sky at any time of the day?
- Solar intensity ("Insolation" = Incident Solar Radiation)
- Average Daily Insolation
- Insolation on collector surfaces



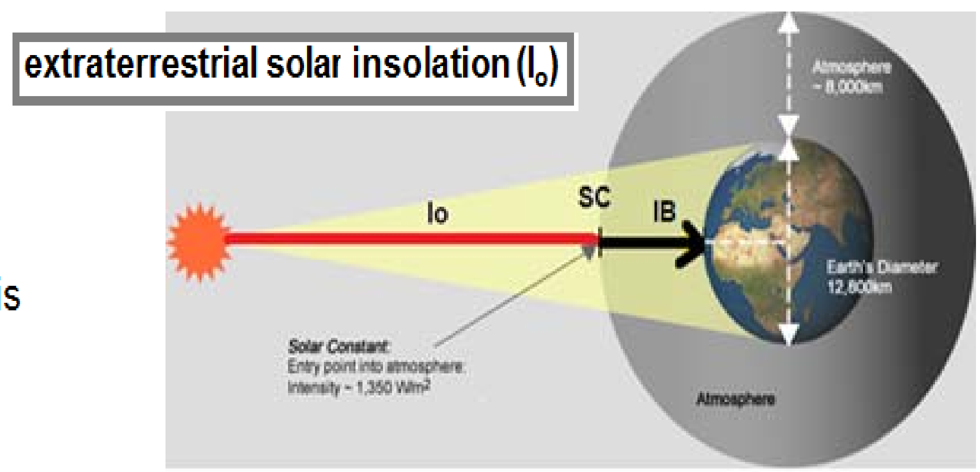
Solar Spectrum



- Sun
  - 1.4 million kilometer diameter
  - Thermonuclear furnace fusing hydrogen atoms into helium
  - 3.8 x 10^{20} MW electromagnetic energy radiation into space



$$4\ {}^{1}H + 2\ e \dashrightarrow {}^{4}He + 2\ \text{neutrinos} + 6\ \text{photons}$$

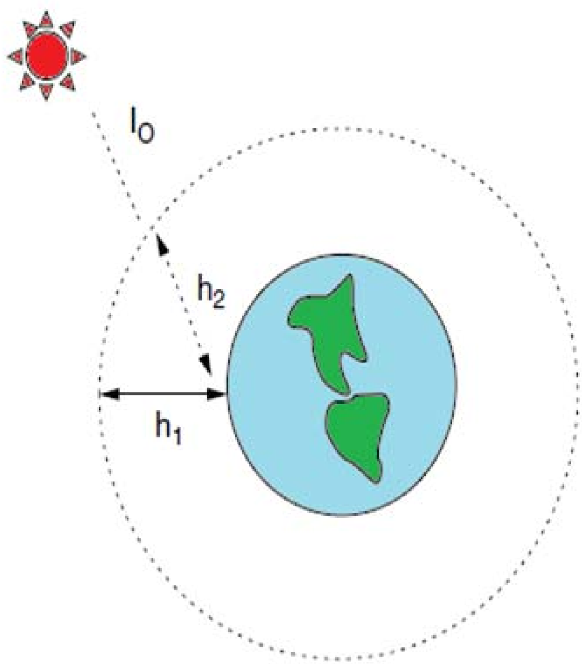


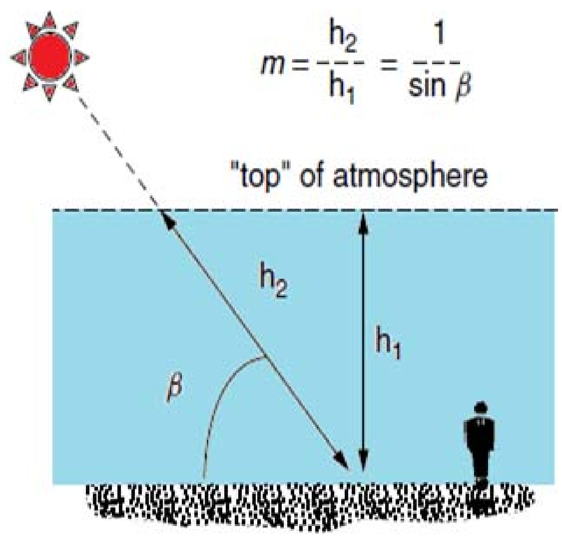
- Solar Spectrum (scaled to have the total area under the curve is 1.37 kW/m^2)
  - UV 7%
  - Visible Light 47 %
  - IR 46%

- **solar insolation** just outside the earth's atmosphere (~ 8000 km) = "**Solar Constant**" = 1.37 kW/m^2

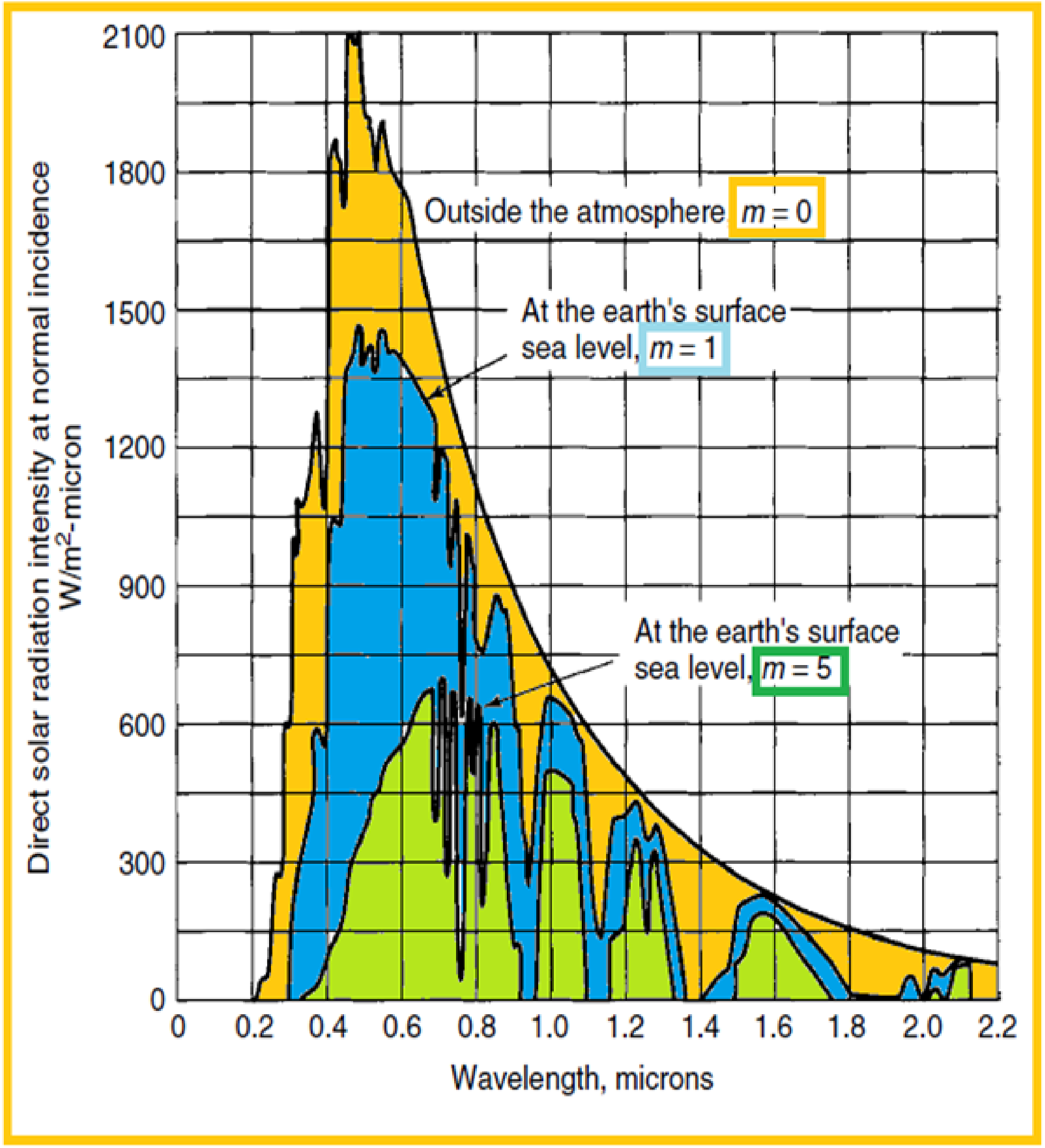
Solar Spectrum Shift by Air Mass Ratio (AM)

- Length of path of sun's rays changes/shifts the solar spectrum



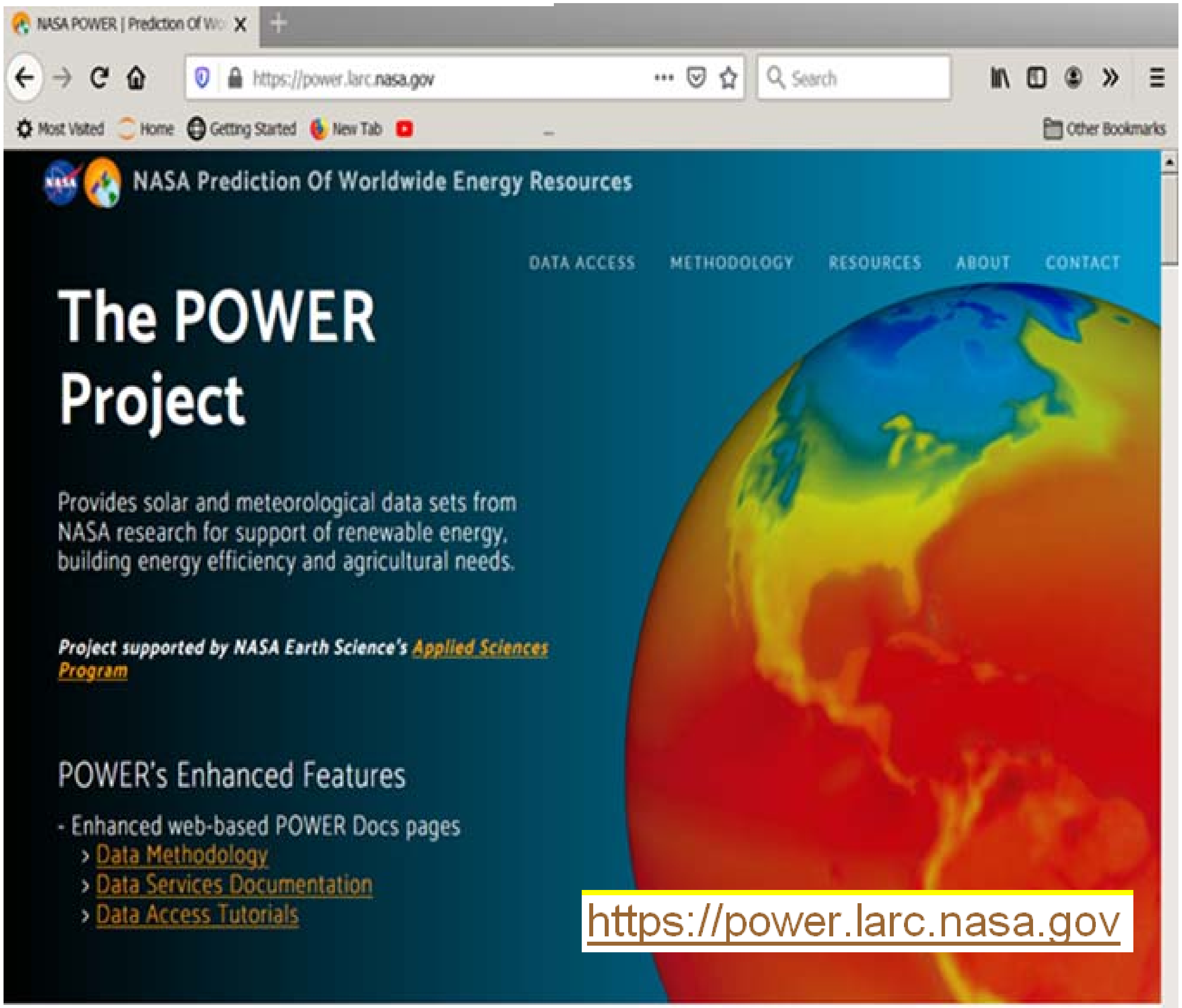


Solar Spectrum



More information on Solar Energy Resources

https://power.larc.nasa.gov



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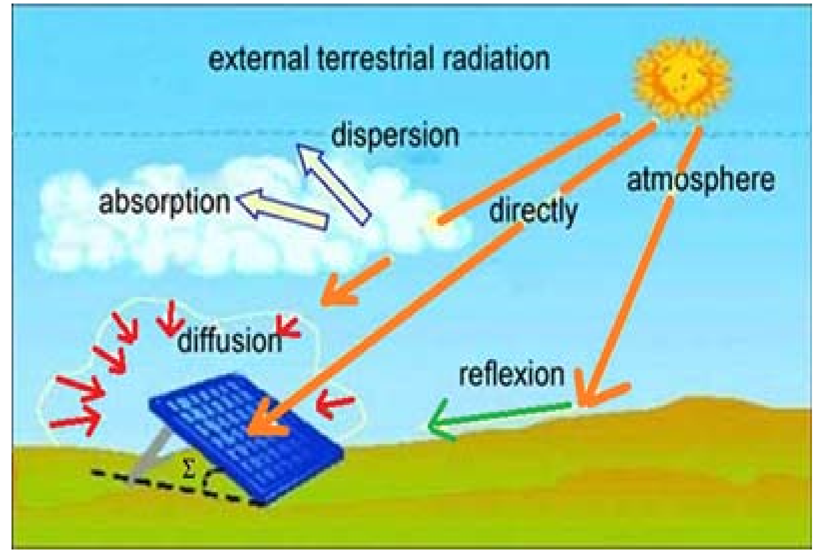
Next Subjects

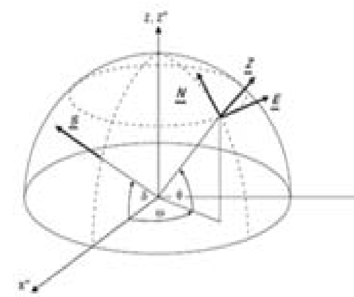
⌘ Our eventual goal of this study



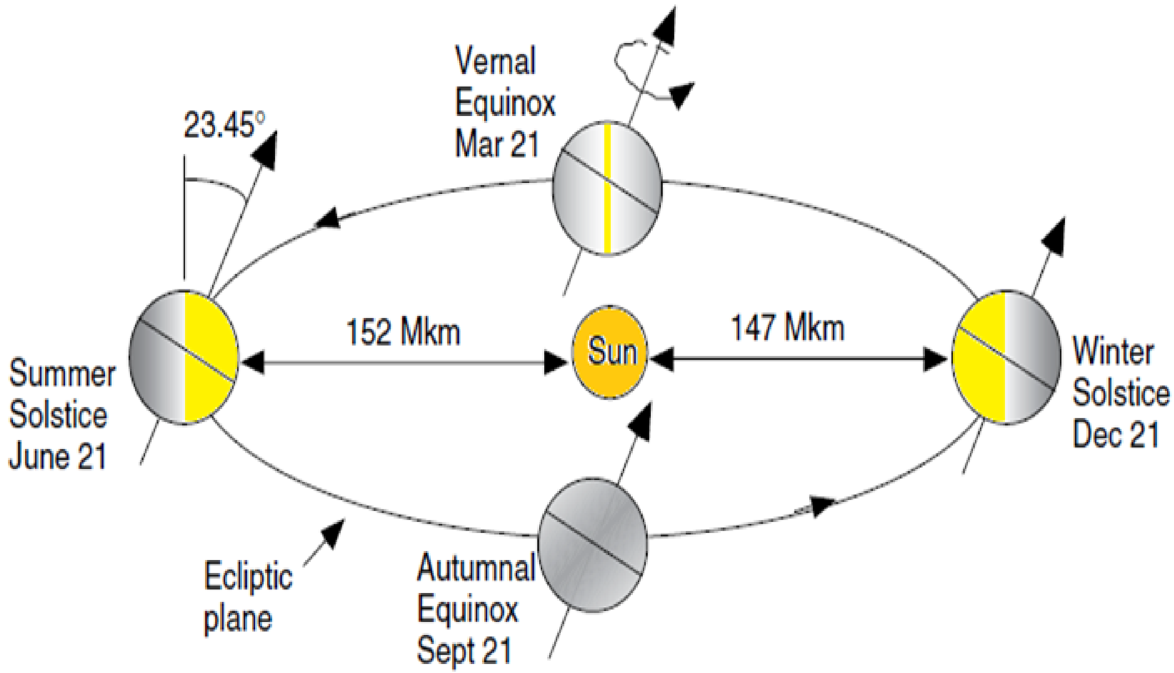
⌘ Basic knowledge we need

⌘ The subjects

⌘ Notice



The Earth's Orbit



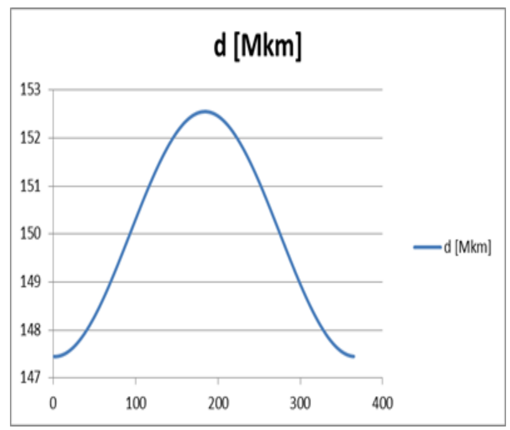
Distance between Sun and Earth on a given day

- *n*: day number (1: Jan 1, 365: Dec 31)
- Angle in **degrees**

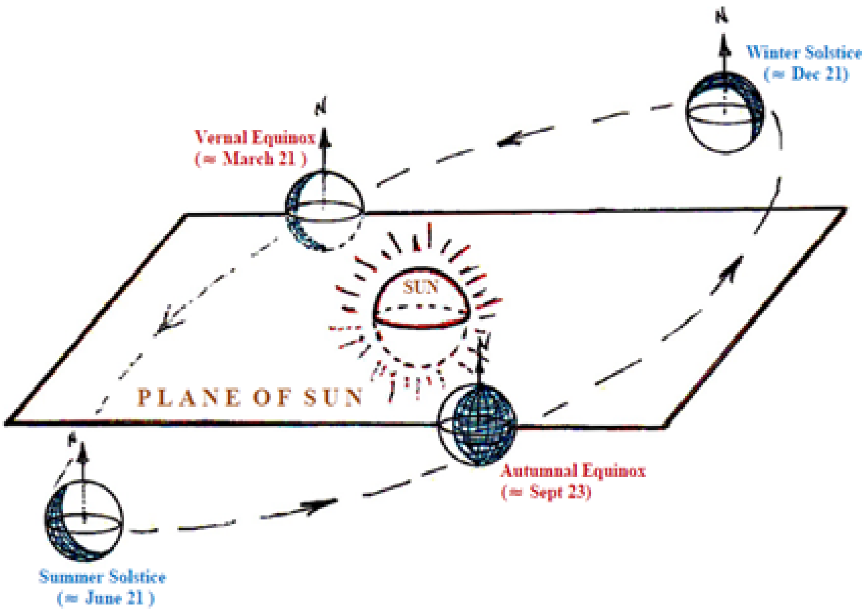
$$d = 1.5 \times 10^8 \left\{ 1 + 0.017 \sin \left[\frac{360(n-93)}{365} \right] \right\} \text{ km}$$

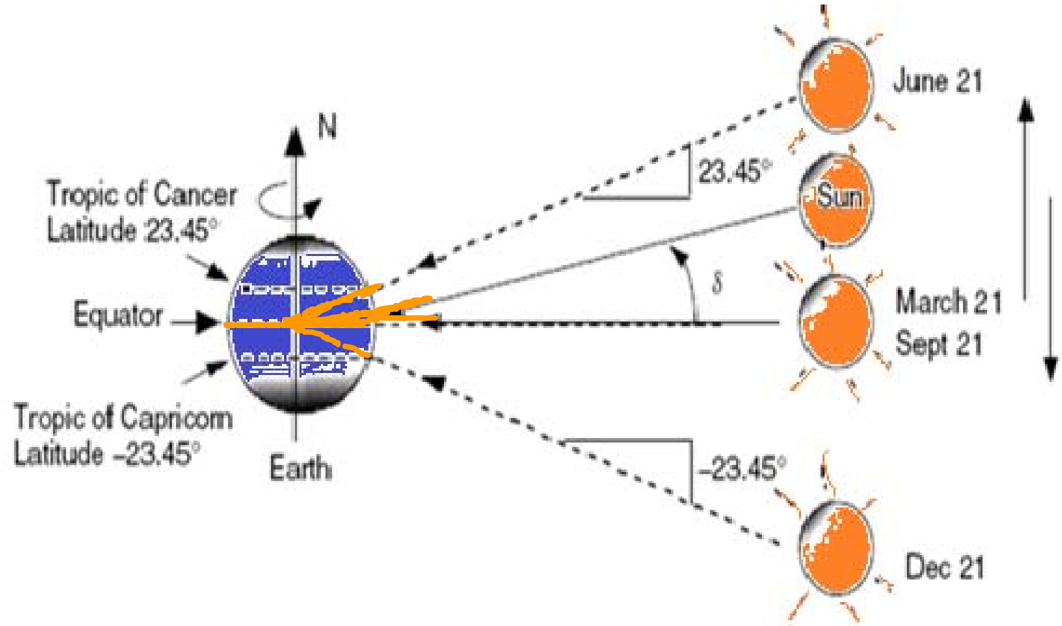
Day Numbers for the First Day of Each Month

January	$n = 1$	July	$n = 182$
February	$n = 32$	August	$n = 213$
March	$n = 60$	September	$n = 244$
April	$n = 91$	October	$n = 274$
May	$n = 121$	November	$n = 305$
June	$n = 152$	December	$n = 335$



Earth's Orbit – Solar Declination





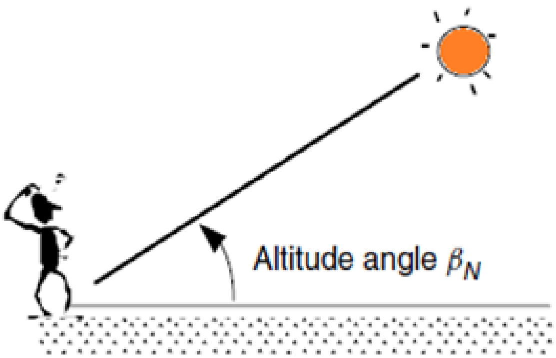
- **<u>Solar declination:</u>** "angle between the sun's rays and the <u>earth's equatorial plane</u>, or the <u>latitude</u> at which the <u>sun is directly overhead</u> at midday.

$$\delta = 23.45^\circ \sin\left[\frac{360}{365}(n-81)\right]$$

Solar Declination δ for the 21st Day of Each Month (degrees)

Month:	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
δ:	−20.1	−11.2	0.0	11.6	20.1	23.4	20.4	11.8	0.0	−11.8	−20.4	−23.4

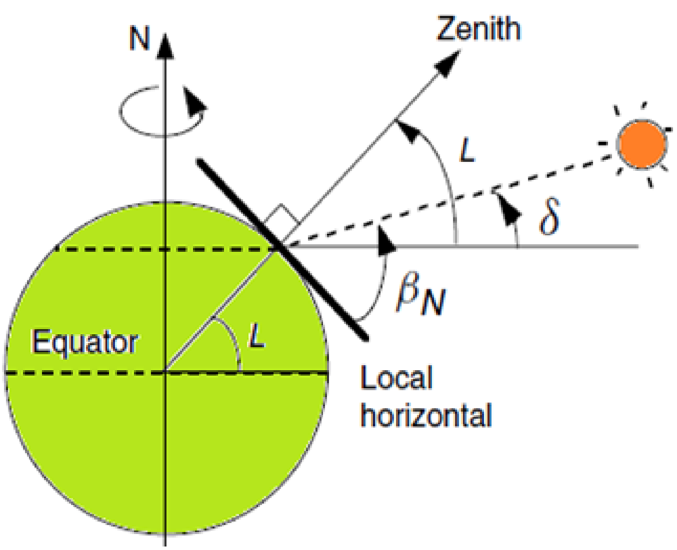
Altitude Angle of the Sun (an Noon) and Solar Declination



$$\delta = 23.45^\circ \sin\left[\frac{360}{365}(n-81)\right]$$

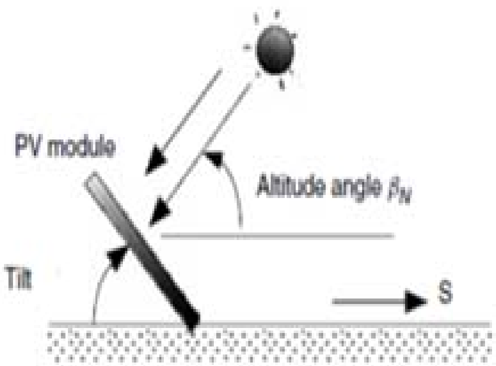
$$\beta_N = (90^\circ - L) + \delta$$

Noon



Example

⌘ Find the optimum tilt angle for a south-facing PV module in Tucson (Latitude 32.1°) at solar noon on March 1.



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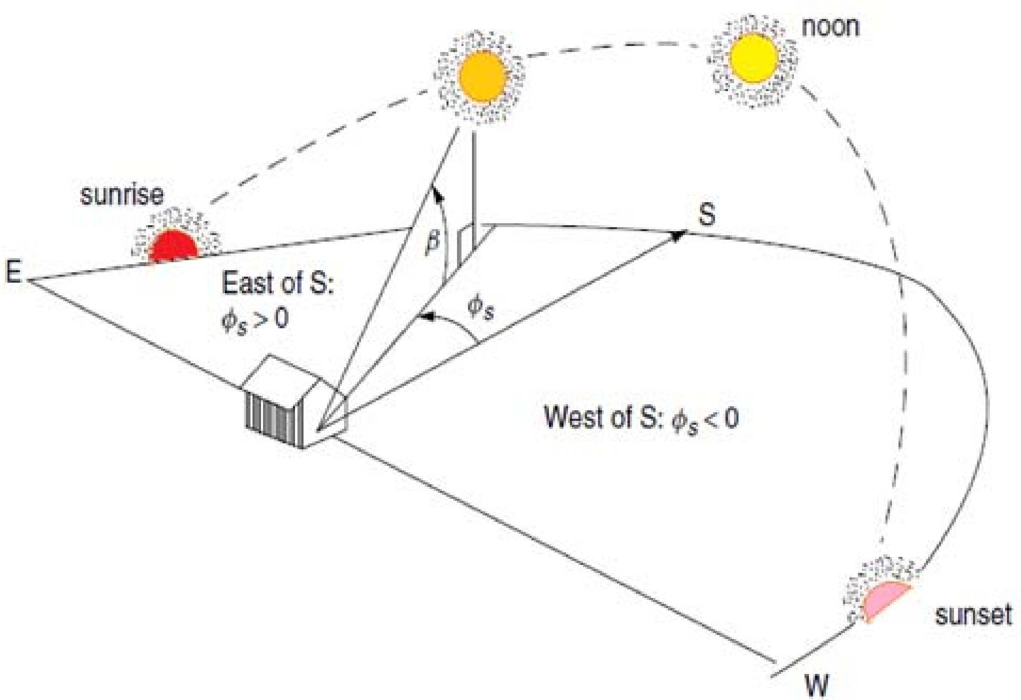
Sun Position at Any Time of Day



Sun Position at Any Time of Day: EXAMPLE

⌘ Question: Find the altitude angle (β) and azimuth angle(ϕ) for the sun at 3:00PM in Boulder, CO (Lat = 40°) on the summer solstice.

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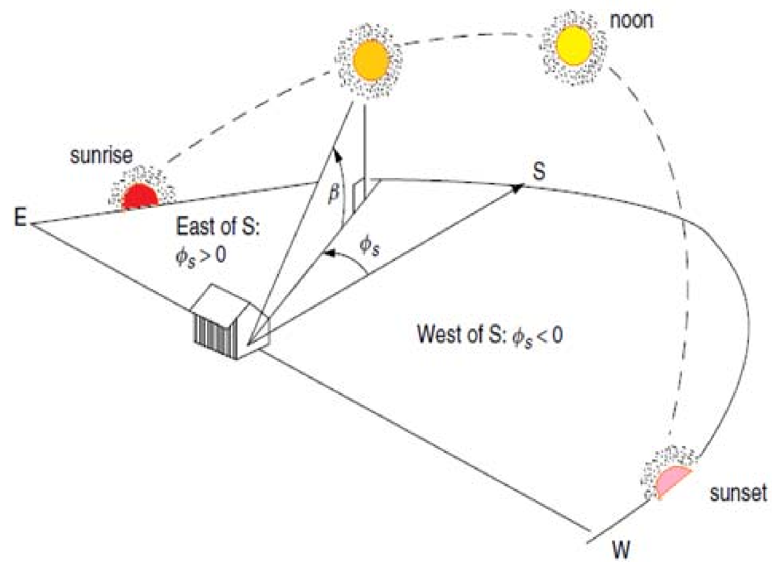
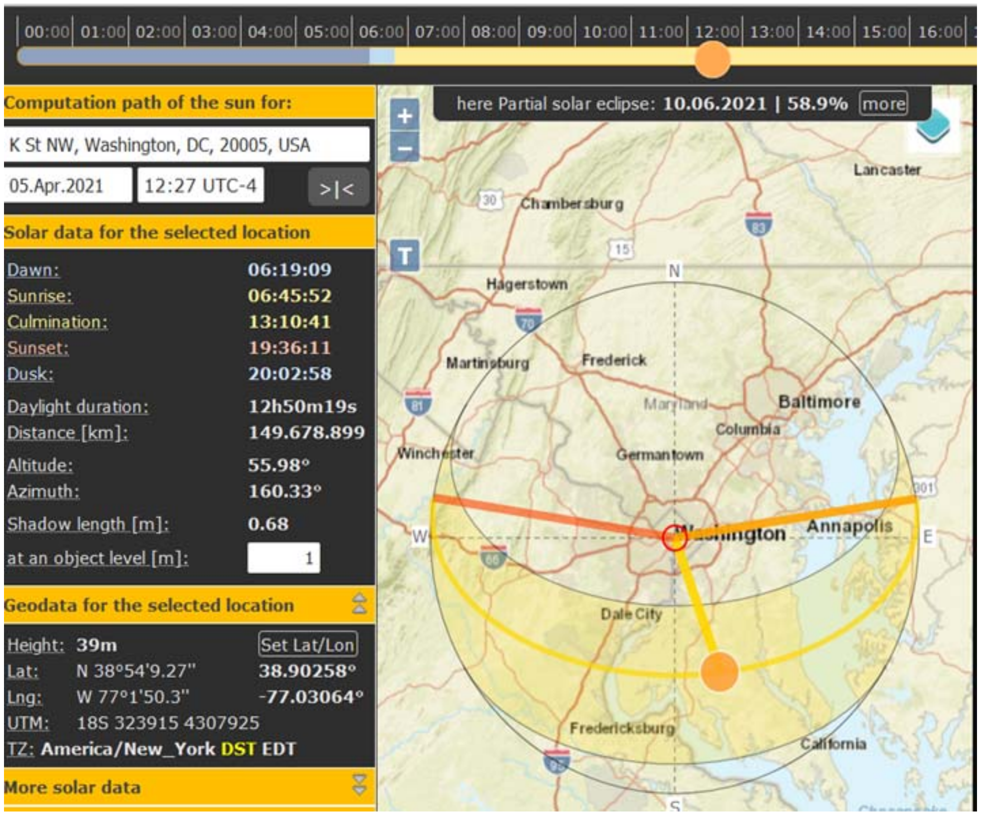


Sun Position Calculator – Web Site

https://www.suncalc.org/



More solar data	
Mar Equinox:	20.03.2021 05:37 EDT
Jun Solstice:	20.06.2021 23:31 EDT
Sep Equinox:	22.09.2021 15:21 EDT
Dec Solstice:	21.12.2021 10:59 EST
Declination:	6.335°
RightAscension:	0h 59m 20.88s

NOAA ESRL
Solar Position Calculator
Earth System Research Lab

https://www.esrl.noaa.gov/gmd/grad/solcalc/