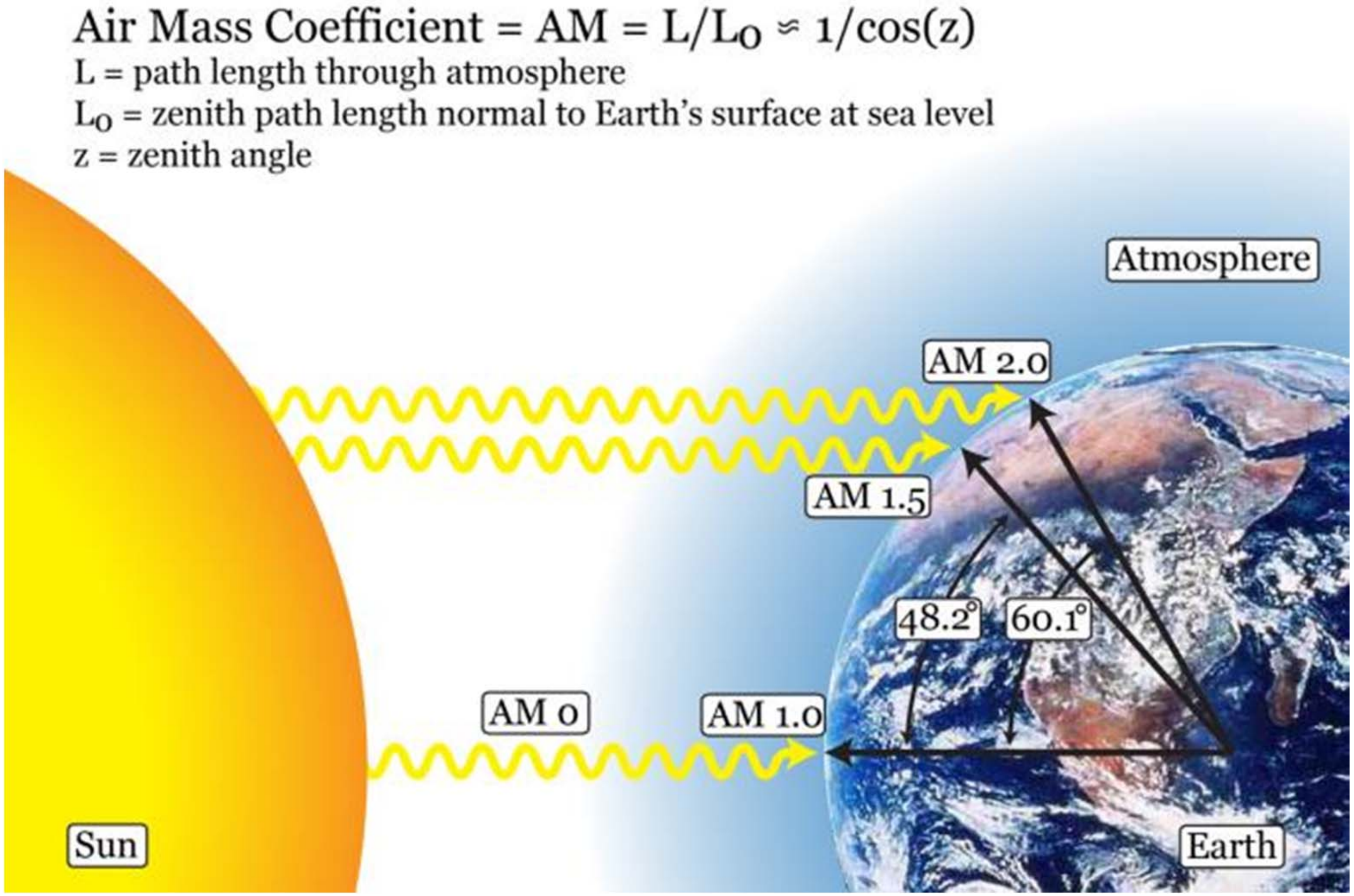
AIR MASS AMm

$m = 1/\cos z$ being z the zenith angle

m is thickness of atmosphere crossed by the light (in unit of «atmosphere»)

(e.g. m = 2 $\rightarrow$ light path is twice the thickness of atmosphere)



AIR MASS defines the *power density* and the *spectrum* of incoming radiation

(see following page)

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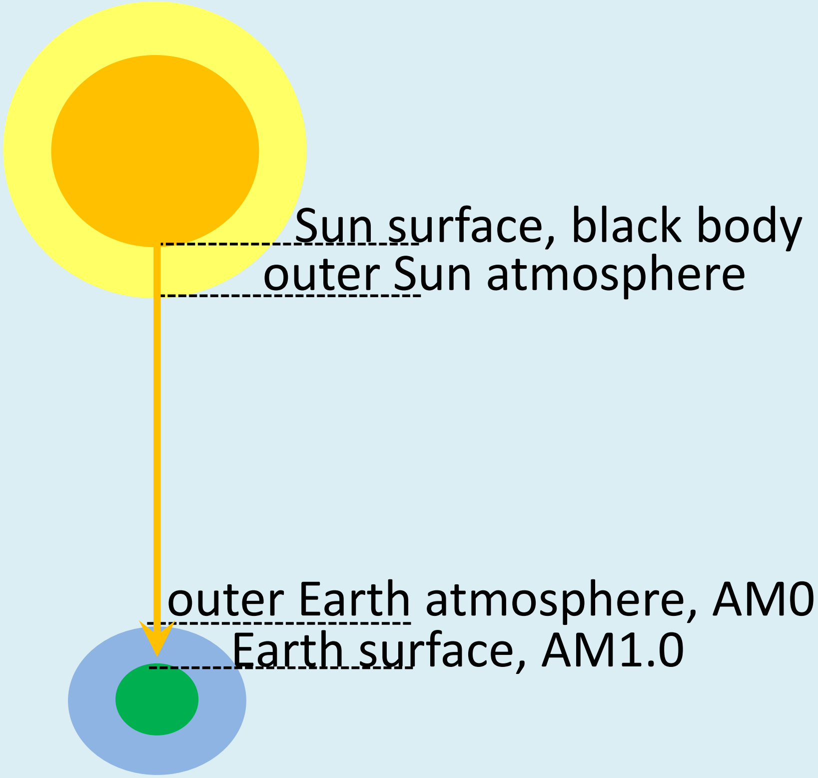
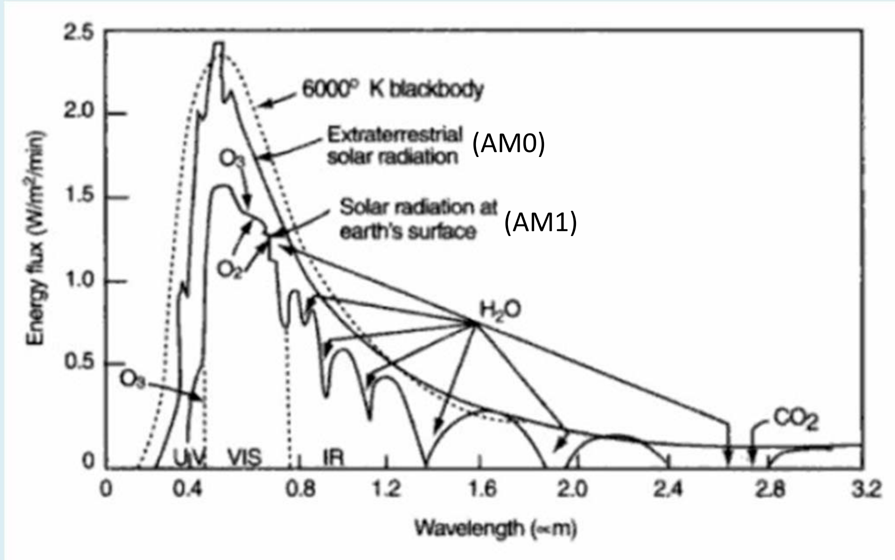
REGIONS

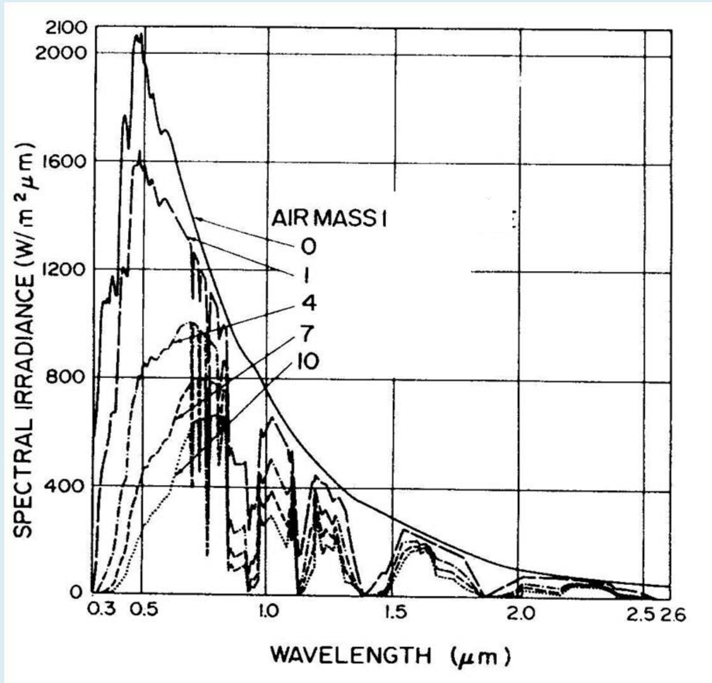


SUN POWER DENSITY

AMm	Θ	W/m²
0	definition	1353
1	0	1040
1.5	48.2°	964
10	85°	270

SUN SPECTRUM





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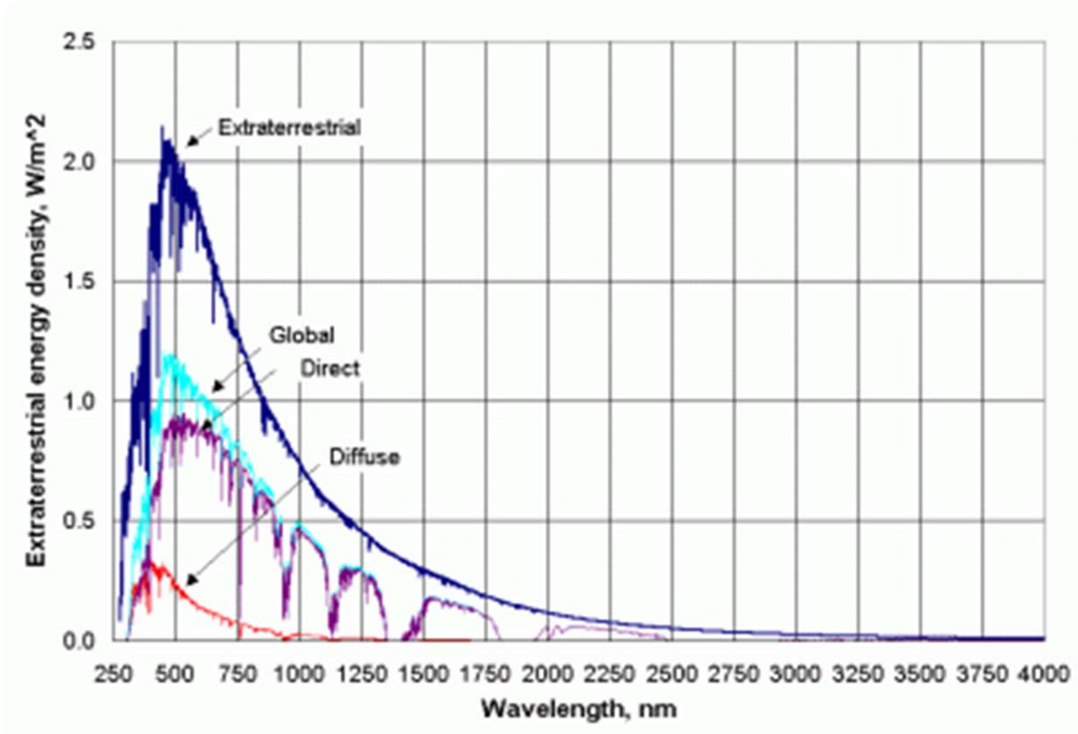
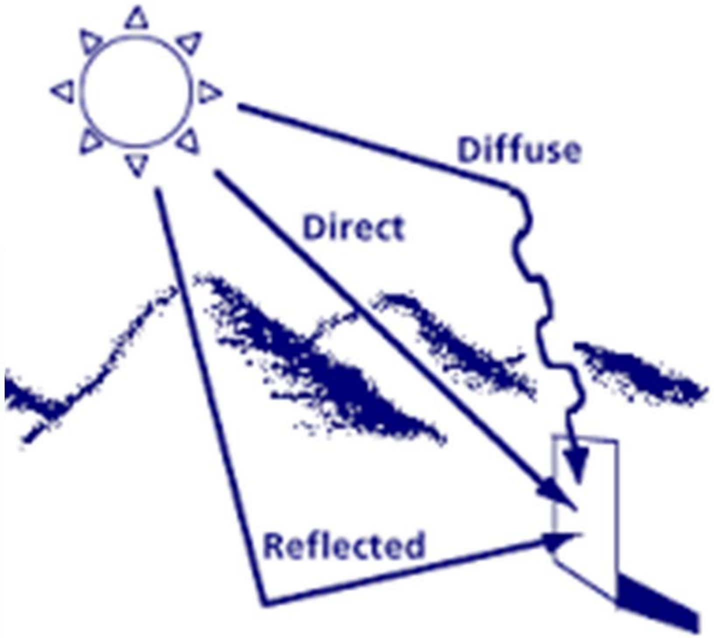
GLOBAL, DIRECT and "CONVENTIONAL" RADIATION

AM1.5G: global radiation 963.8 W/m^2
AM1.5G: direct radiation 768.3 W/m^2





Diffuse light is mainly blue
↓
sky is mainly blue

BUT!

Conventionally AM1.5 (Earth surface, $\Theta = 48.2°$) is defined to be 1000 W/m^2 , in order to simplify the calculations

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FROM SUN POWER DENSITY TO SUN ENERGY DENSITY

Sun power density, G(t): sun power reaching the Earth surface [W/m^2] at a certain time t, also known as *global radiation.*

Sun energy density, H(Δt): sun power density x radiation duration [Wh/m^2], aka *global insolation*. Since power density is not constant during the day this should rather be defined as $\int G(t)dt$. This integral gives the cumulate energy that reached a m^2 during a period of time Δt.

Example.

In order to know which is the annual global insolation of a certain place is necessary to measure the G(t) (normally done by means of pyranometers) and integrate it over the whole year.

1 year = 8760 hours, clearly almost half of the time no sun will shine, and for the rest of time its intensity will not always be at 1 kW/m^2. That is why the average swiss global insolation is around 1100 kWh/m^2, whereas in Sahara desert is around 2400 kWh/m^2.

We could also say that in Switzerland the Sun shines every year for 1100 hours at the intensity defined by AM1.5G (=1 kW/m^2). This is a useful point of view due to the fact that the nominal power (P_n) of the module is measured under STC (1 kW/m^2, AM1.5G and 25°C). Therefore during a year a module installed in Switzerland (Sahara) will work for 1100 (2400) hours at its nominal power.

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FROM SUN ENERGY DENSITY TO ELECTRICAL ENERGY

Sun energy, $E_{in}(\Delta t, S)$: sun energy density x surface [W], clearly a larger surface S will receive more incoming energy.

Electrical energy $E_{el}(\eta)$: sun energy x PV-module efficiency [W], by comparing two modules having the same surface, the one with 20%-efficiency produce twice more energy than the 10%-one.

Summarizing:

$$E_{el}(G(t), \Delta t, S, \eta) = \left[\int_{\Delta t} G(t)dt\right] \times S_{PV} \times \eta_{PV}$$

From equation you see that in order to meet an energy demand E_{el} if you are limited by surface S you have to install high efficiency PV-modules. Instead if you have enough surface (shed roofs, highway guardrails, …) you can choose to install lower efficiency PV-modules.

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