Solar energy resources

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Why solar energy?

- Practically all energy in the Earth apart from geothermal comes from the sun
- Sun deities all over the globe
- Centre of the solar system
- Sun plays major role in most cultures

Anyanwu, Igbo god believed to dwell in the sun

Magec, Tenerife god of the sun and light

Mawu, Dahomey goddess associated with the sun and the moon

Ngai, Kamba, Kikuyu and Maasai god of the sun

Bila, cannibal sun goddess of the Adnyamathanha

Gnowee, solar goddess who searches daily for her lost son; the light of her torch is the sun

Wala, solar goddess

Wuriupranili, solar goddess whose torch is the sun

Yhi, Karraur goddess of the sun, light and creation

Chup Kamui, a lunar goddess who switched places with her brother to become goddess of the sun

Malakbel, god of the sun

Shams/Shamsun, a solar goddess exalted in Himyar and by the Sabaeans.[1][2][3][4]

Huitzilopochtli, god of the sun and war

Nanauatzin, god of the sun

Teoyaomicqui, god of lost souls, the sun and the sixth hour of the day

Tonatiuh, god of the sun and ruler of the heavens

Xiuhtecuhtli, god of fire, day and heat

Saulė, goddess of the sun and fertility

Ekhi, goddess of the sun and protector of humanity

Meri, folk hero and god of the sun

Marici, goddess of the heavens, sun and light

Surya, the deity of the sun (Suriya Pariththa, Suthra Pitaka, Pali canon, Theravada Buddhism)

Shapash, goddess of the sun

Áine, Irish goddess of love, summer, wealth and sovereignty, associated with the sun and midsummer

Alaunus, Gaulish god of the sun, healing and prophecy

Belenos, Gaulish god of the sun

Gronw Pebr, Welsh figure occasionally constructed as a god of light.

Étaín, Irish sun goddess

Epona, horse deity occasionally linked with Étaín.

Grannus, god associated with spas, healing thermal and mineral springs, and the sun

Olwen, female figure often constructed as originally the Welsh sun goddess.

Sulis, British deity whose name is related to the common Proto-Indo-European word for "sun" (and thus cognate with Helios, Sól, Sol, Usil and Surya) and who retains solar imagery, as well as a domain over healing and thermal springs. Probably the de facto solar deity of the celts.

Statue of the goddess Xihe charioteering the sun, being pulled by a dragon, in Hangzhou

Doumu, sun goddess sometimes conflated with Marici.

Yuyi, the sun god

Xu Kai, the god of the sun-star

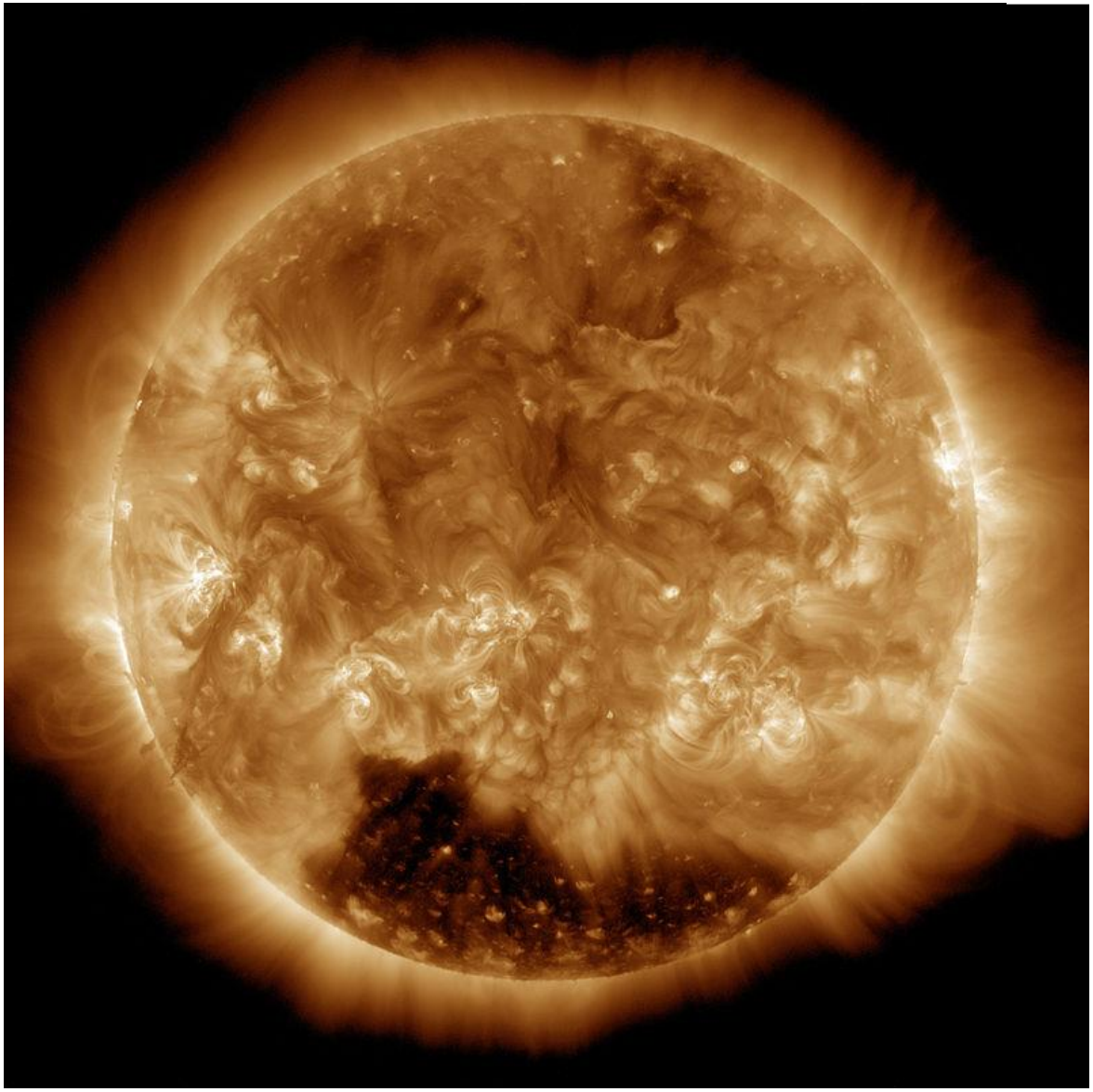
Xihe, sun goddess and mother of the ten suns

Zhulong, dragon deity of daylight.

Bastet, cat goddess associated with the sun

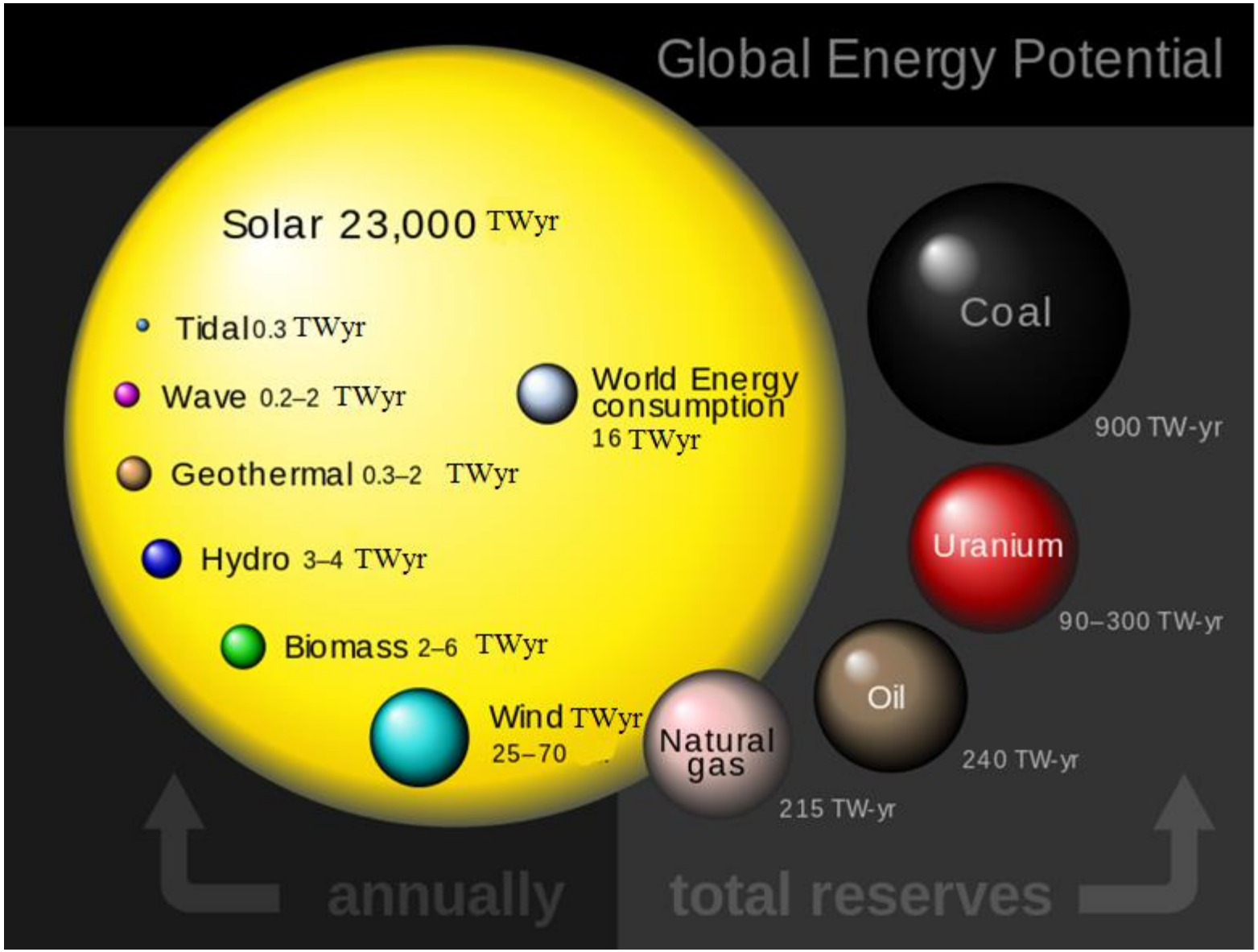
Horus, god of the sky whose right eye was considered to be the sun and his left the moon

Only a few Sun deities in different places ….



Astronomy facts

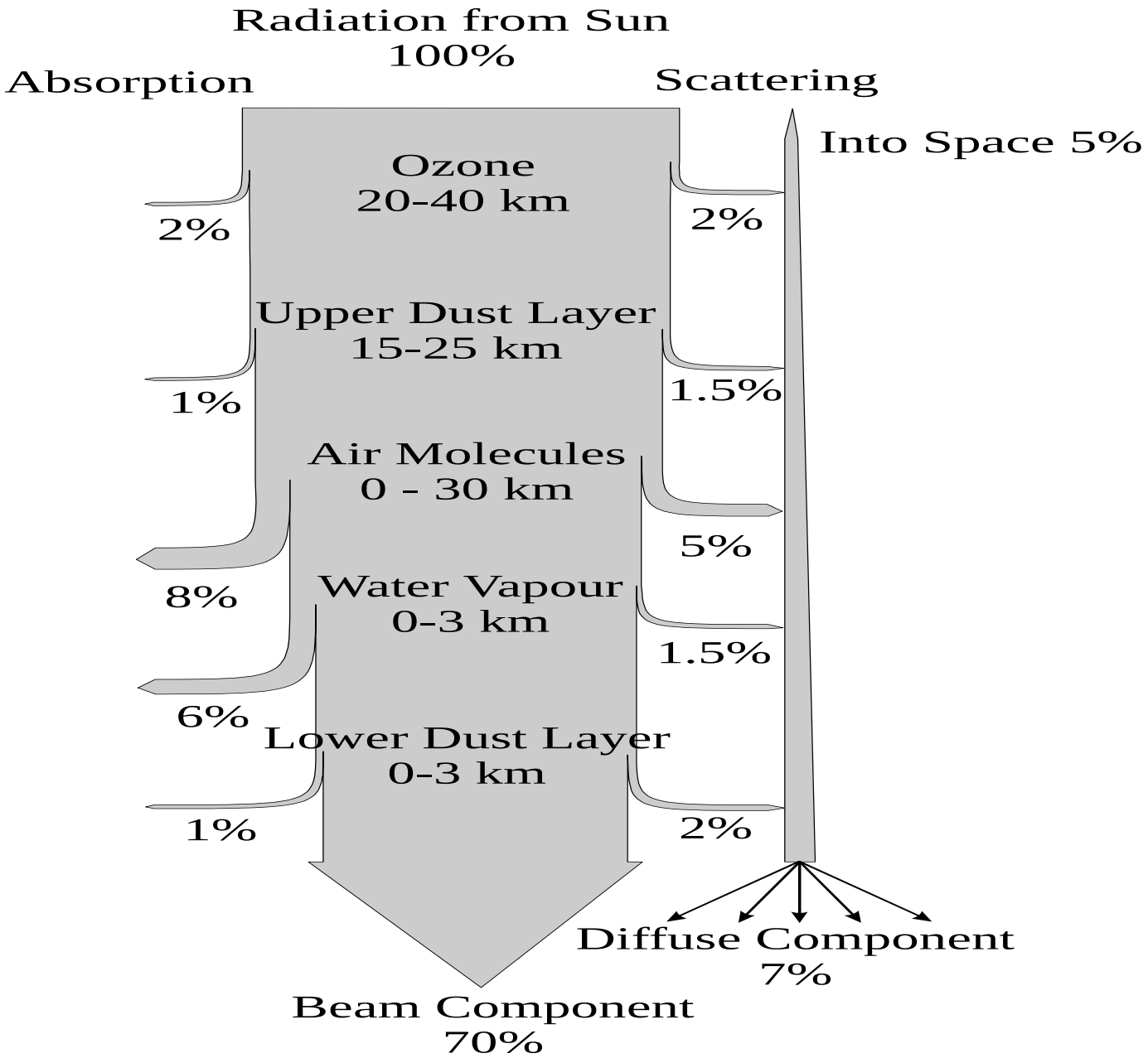
- G-type main sequence star
- 99.86% of the total mass of our solar system
- Mean distance to the Earth 1 AU=150,000,000 km
- Almost 75% Hydrogen, 25% Helium, trace of other elements by mass
- Energy primarily made from fusion of Hydrogen into helium. (proton-proton reaction)
- Small amounts of energy from carbon-oxygen-nitrogen cycle(CNO cycle)

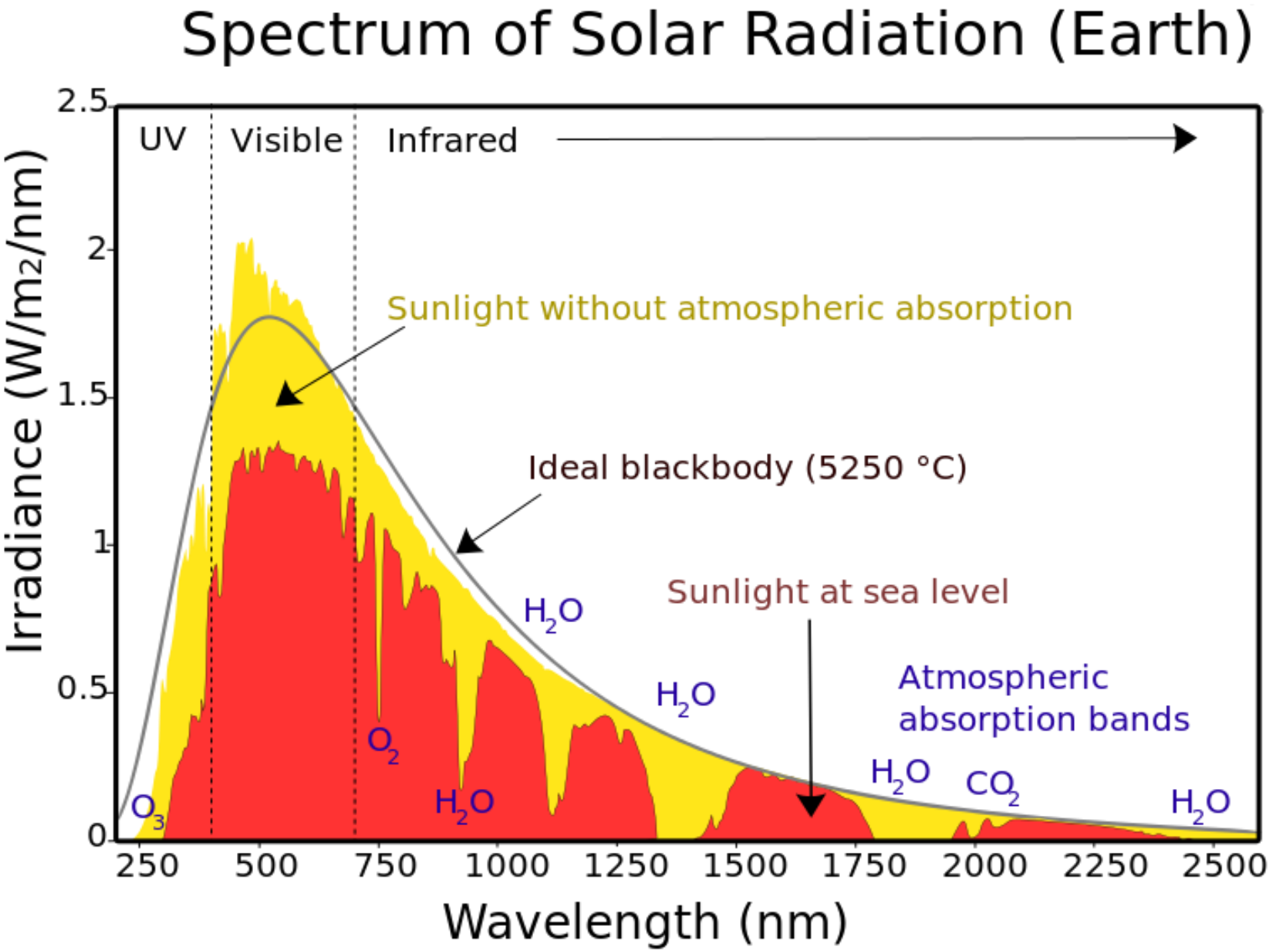

Global Energy Potential
Solar 23,000 TWyr
Tidal 0.3 TWyr
Wave 0.2–2 TWyr
World Energy consumption 16 TWyr
Geothermal 0.3–2 TWyr
Hydro 3–4 TWyr
Biomass 2–6 TWyr
Wind TWyr 25–70
Coal
900 TW-yr
Uranium
90–300 TW-yr
Oil
240 TW-yr
Natural gas
215 TW-yr
annually
total reserves

Facts about solar energy

- The earth receives 174 PW of solar radiation
- Insolation refers to the total amount of solar radiation energy received on a given surface, MJ/m^2. Can also use Wh/m^2.
- Irradiance is the power (radiant flux) received over a surface and is measured in W/m^2
- Sunlight is electromagnetic radiation from the sun in the infrared, visible and UV light
- No cloud coverage, direct light
- Cloud coverage, diffuse light
- Nothing more than photons

- Energy received from the sun is 3.3% higher than average in January and 3.3% lower in July.
- Extraterrestrial solar radiation is 1367 W/m^2
- Earth's surface at zenith is 1050W/m^2, total amount is 1120W/m^2
- Out of it: 52-55% infrared (above 700 nm) 42-43 % visible (400 to 700 nm), 3-5% UV (below 400 nm)


Radiation from Sun
100%
Absorption
Scattering
Into Space 5%
Ozone
20-40 km
2%
2%
Upper Dust Layer
15-25 km
1%
1.5%
Air Molecules
0 - 30 km
5%
8%
Water Vapour
0-3 km
1.5%
6%
Lower Dust Layer
0-3 km
1%
2%
Diffuse Component
7%
Beam Component
70%


Spectrum of Solar Radiation (Earth)
UV
Visible
Infrared
Sunlight without atmospheric absorption
Ideal blackbody (5250 °C)
Sunlight at sea level
Atmospheric absorption bands
O_3
O_2
H_2O
H_2O
H_2O
H_2O
CO_2
H_2O
Irradiance ($W/m^2/nm$)
Wavelength (nm)
0
0.5
1
1.5
2
2.5
250
500
750
1000
1250
1500
1750
2000
2250
2500

Spectrum

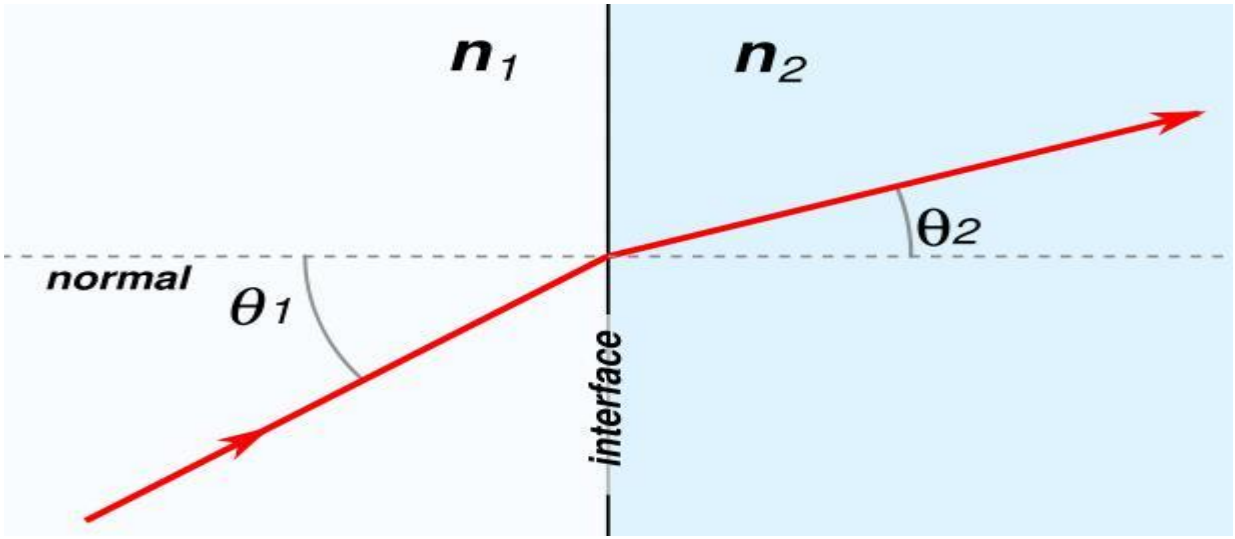
- Spectrum: mixture of Photons with different energies
- light with different energy has a different colour
- not possible to filter indefinitely

Interaction of light with matter

- Transmission
- Reflection
- Absorption/re-emission
- Scattering
  - Mie (particles > wavelength)
  - Rayleigh (particles << wavelength)

Reflection/refraction

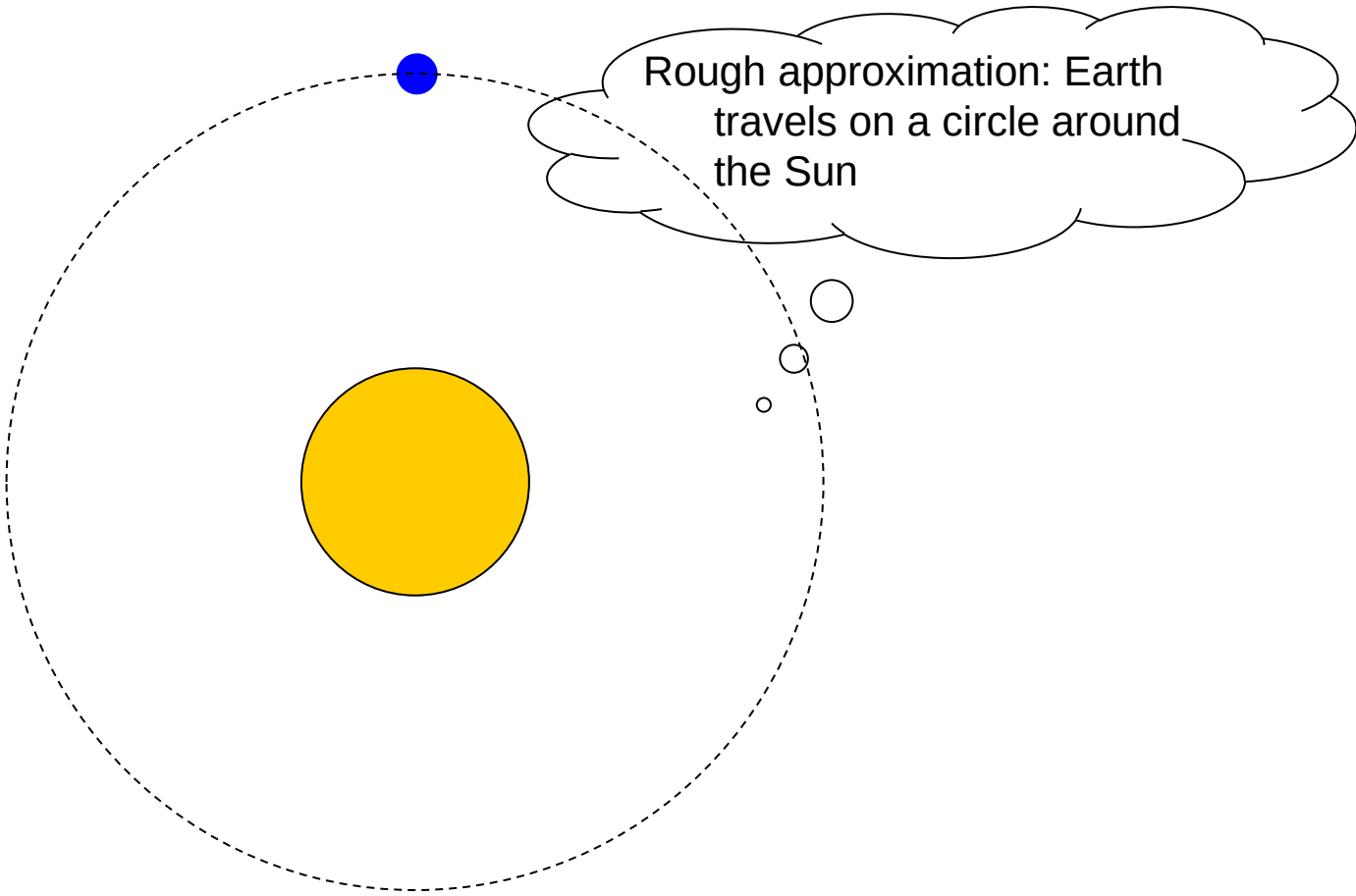
- Wavelength of light changes according to optical density or refractive index n
- Frequency is constant
- Energy is constant
- Snell's law $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$



Scattering

- blue light is scattered more than red
- blue photons are scattered around the sky
- sky is blue at noon
- at sunset/sunrise the additional distance to travel through atmosphere results in blue light being scattered away, resulting in red hue around the Sun

Sun-earth geometry



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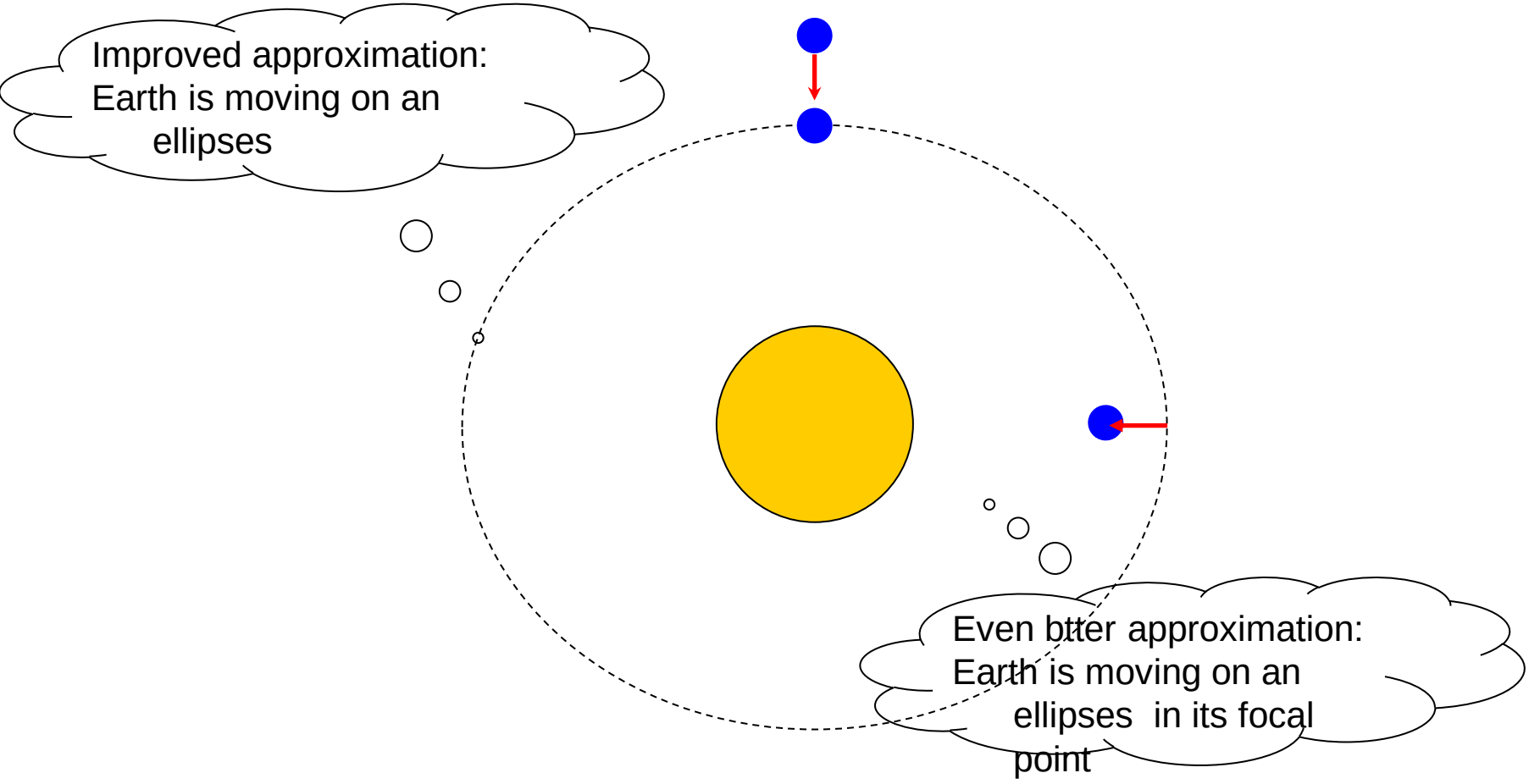

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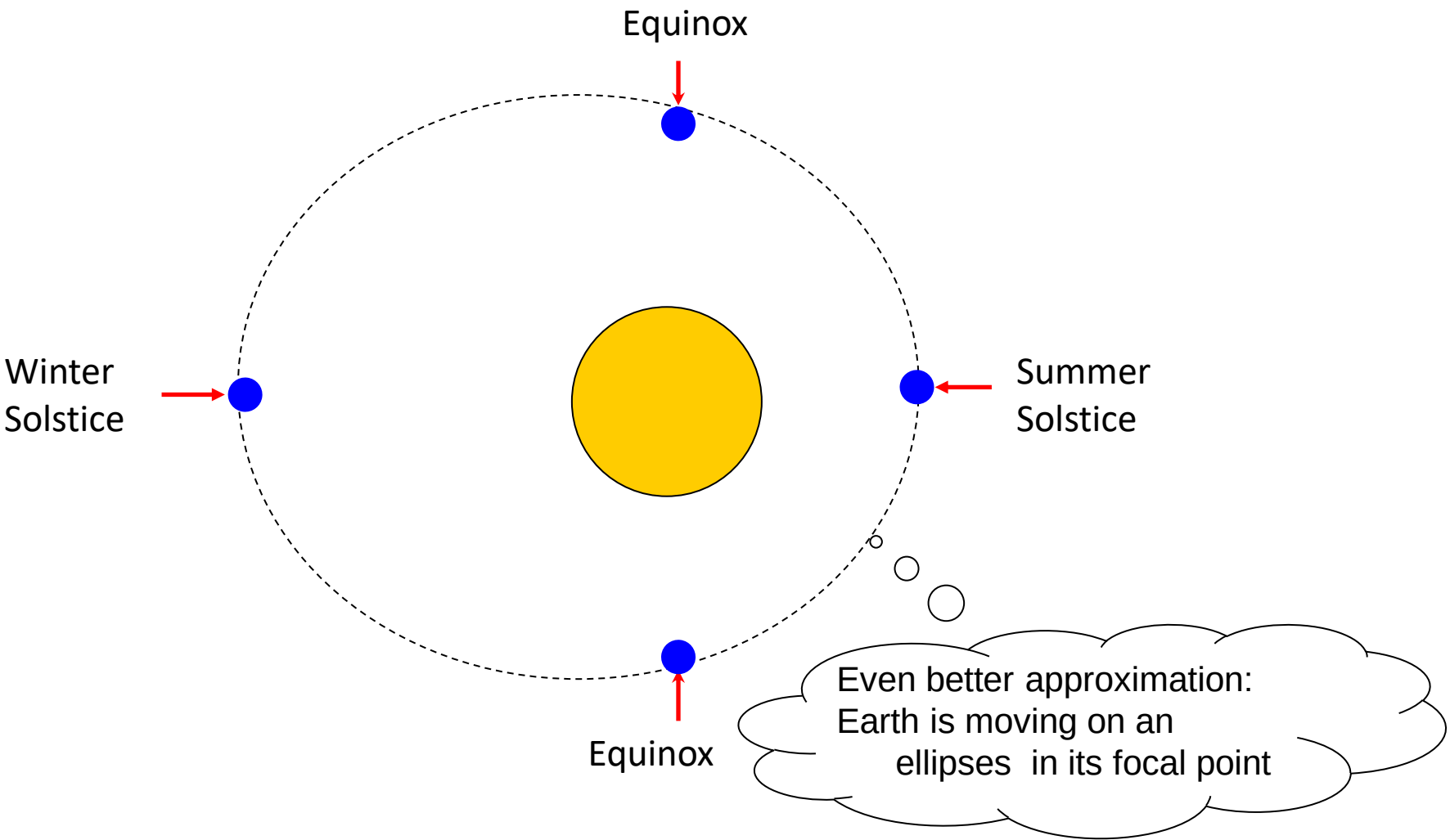
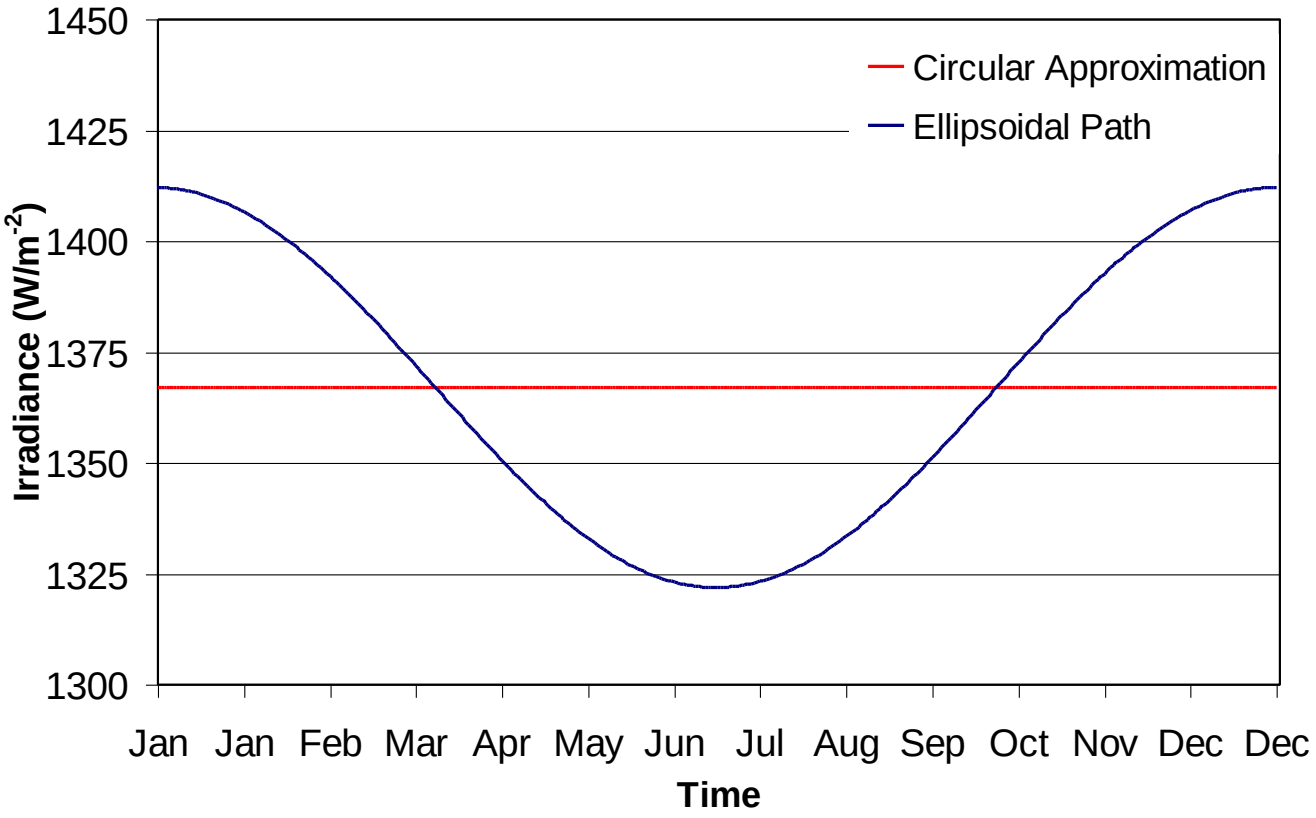
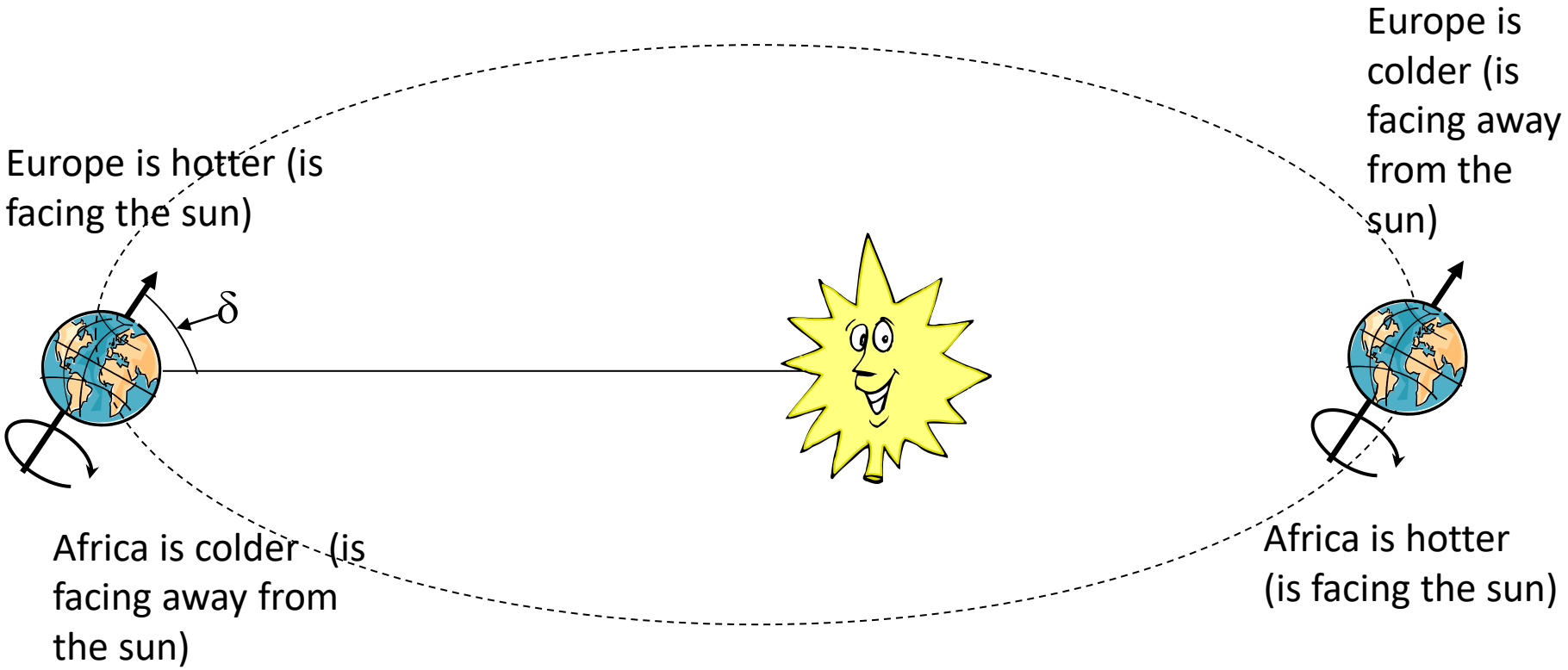


Irradiation outside atmosphere

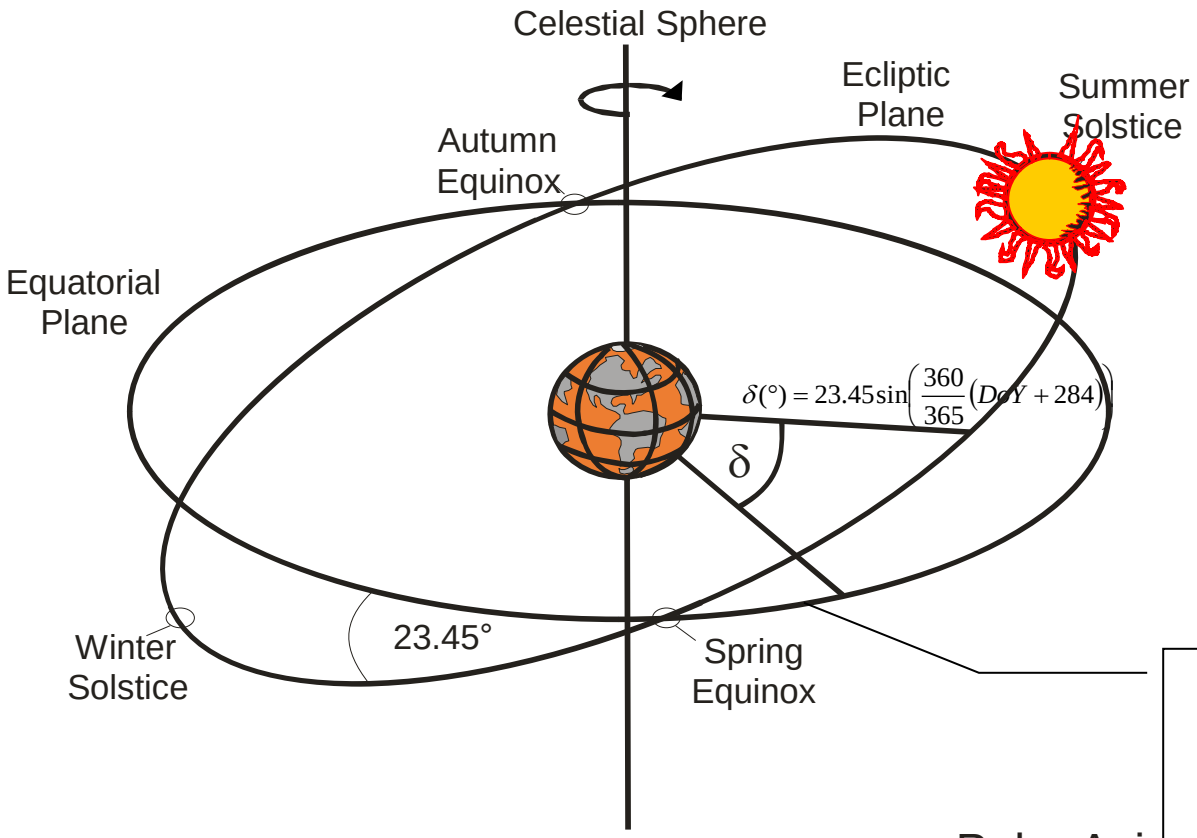


Movement of earth around the sun

- Earth rotates around its axis
- Earth's rotational axis is angled at δ=23.45^{o} to the rotation around the Sun
- Ellipsoidal movement around Sun



Perceived movement of sun around the Earth

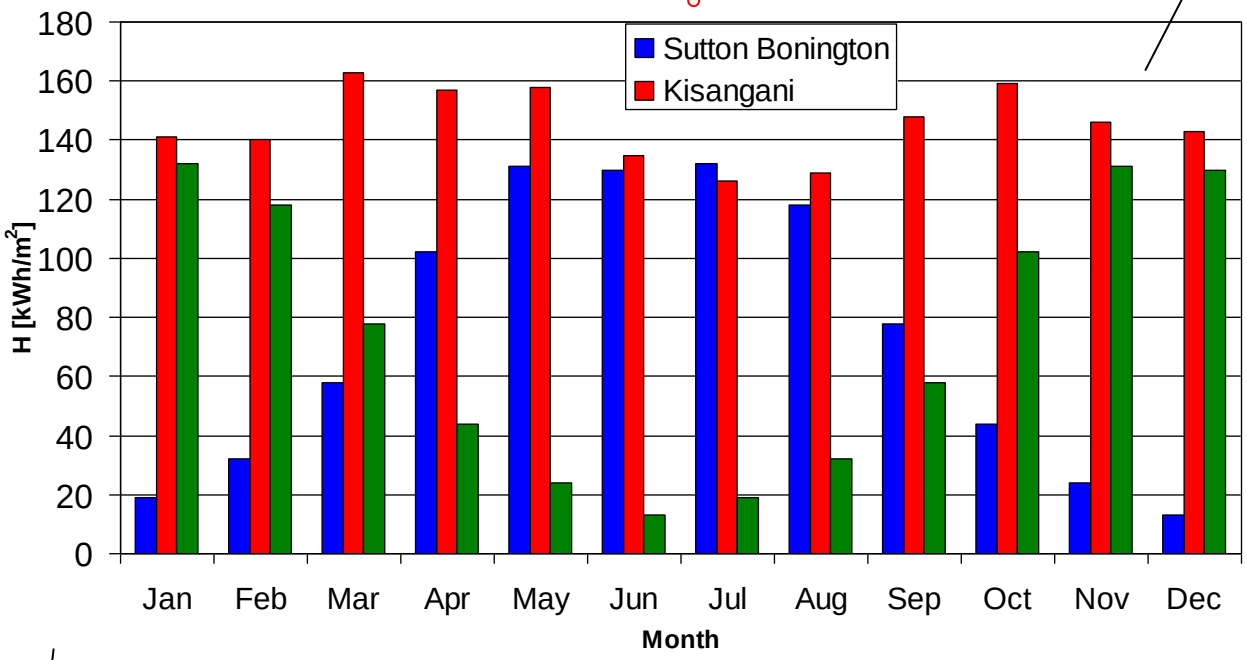


DoY: Day of Year

Seasonal variation

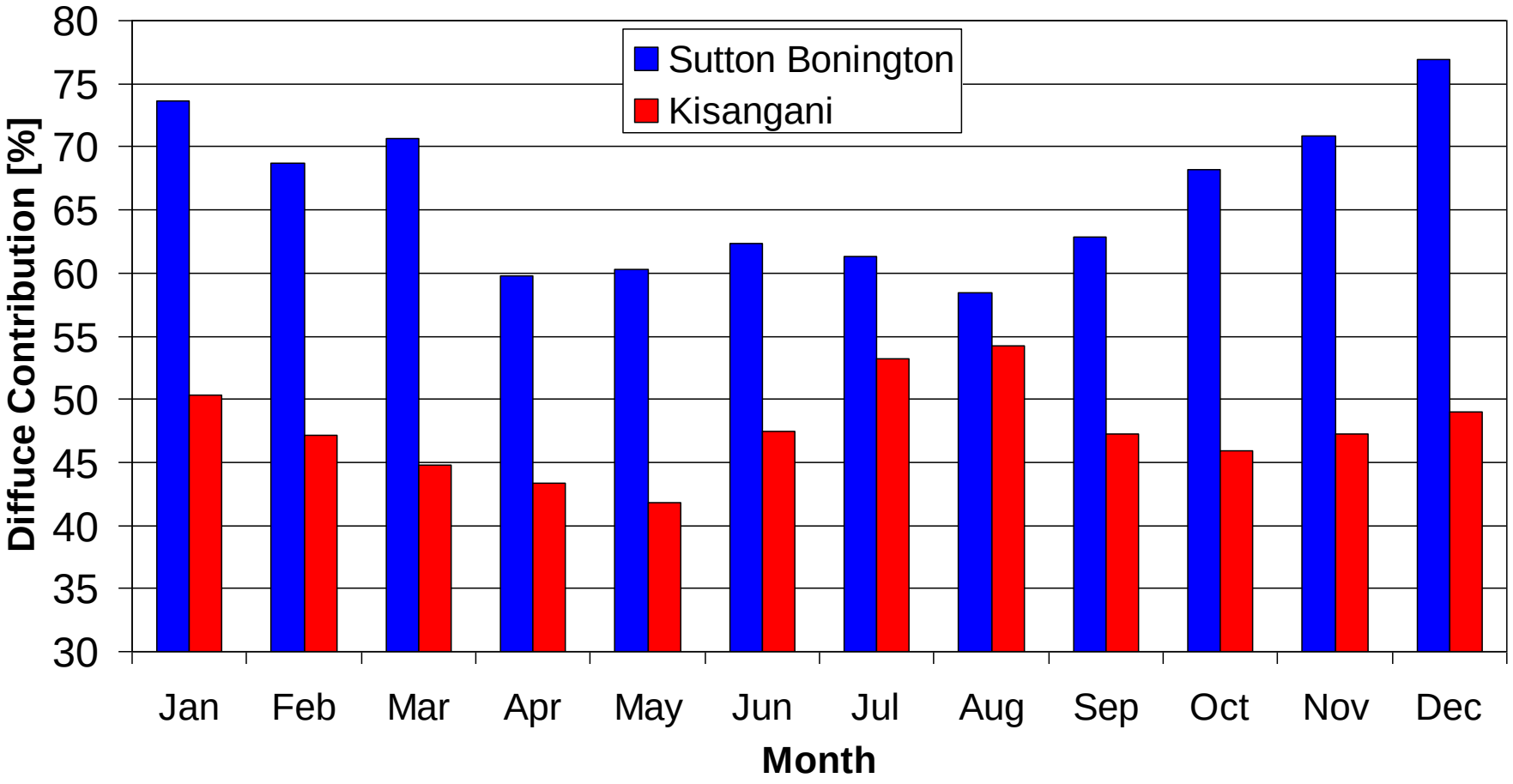
What would be the pattern like Sutton Bonington for a city located at a mirror latitude in the south hemisphere?

1745 kWh/m²



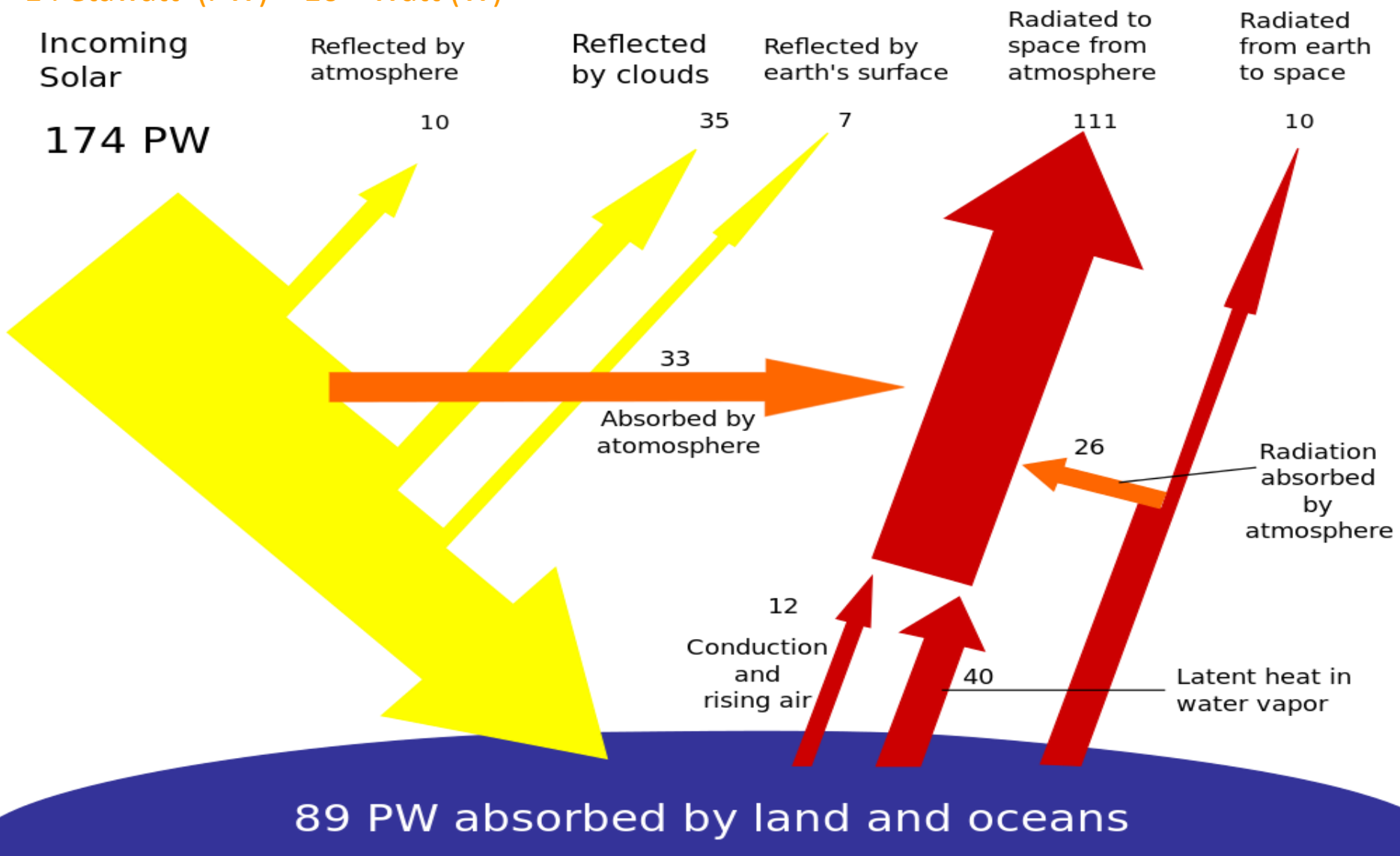
881 kWh/m²

Diffuse radiaton

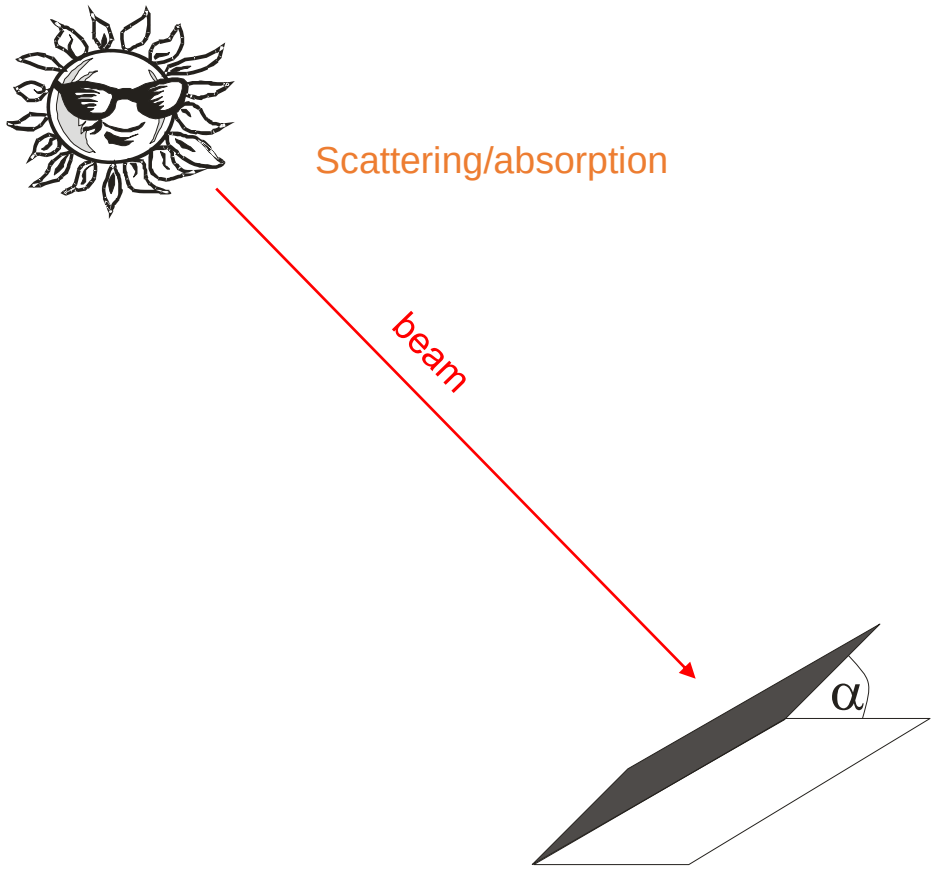


Breakdown of incoming solar radiation

1 Petawatt (PW) = 10^{15} Watt (W)



How does the sun affect a surface



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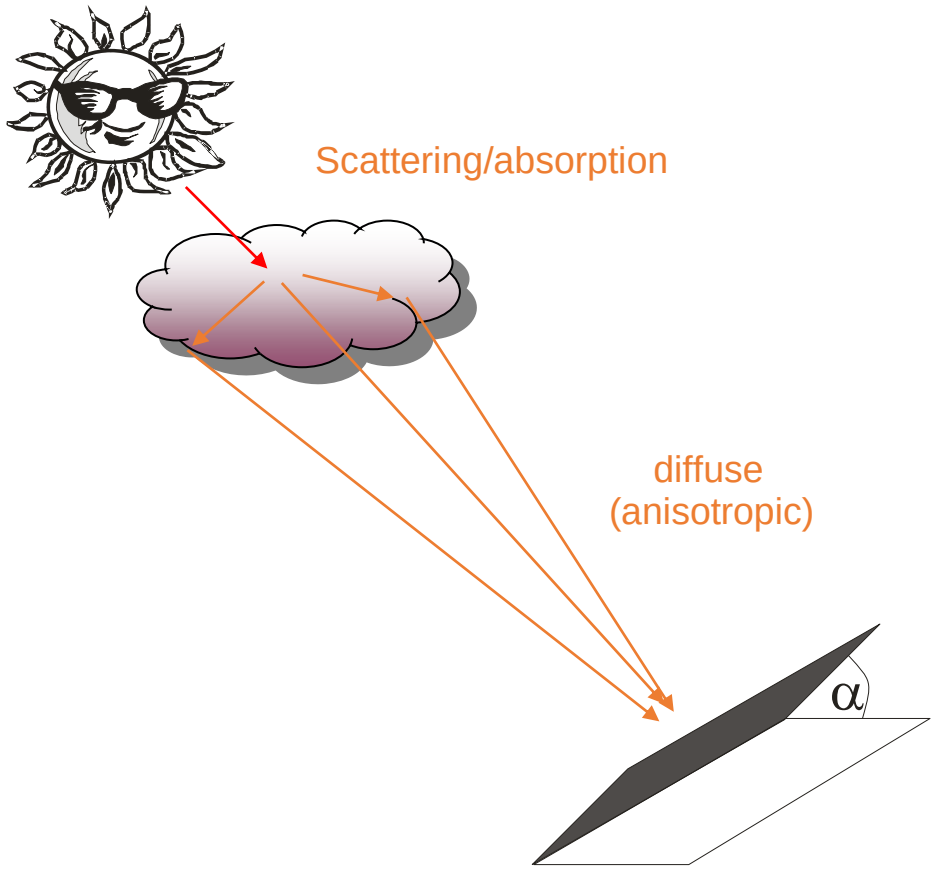
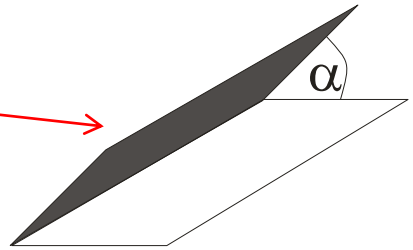


How does the sun affect a surface

Scattering/absorption

Material	**Albedo**
Aluminium	0.85
Asphalt	0.09-0.15
Concrete	0.25-0.35
Fresh Snow	0.82
Galvanised Steel	0.1-0.35
Grass	0.15-0.25

albedo



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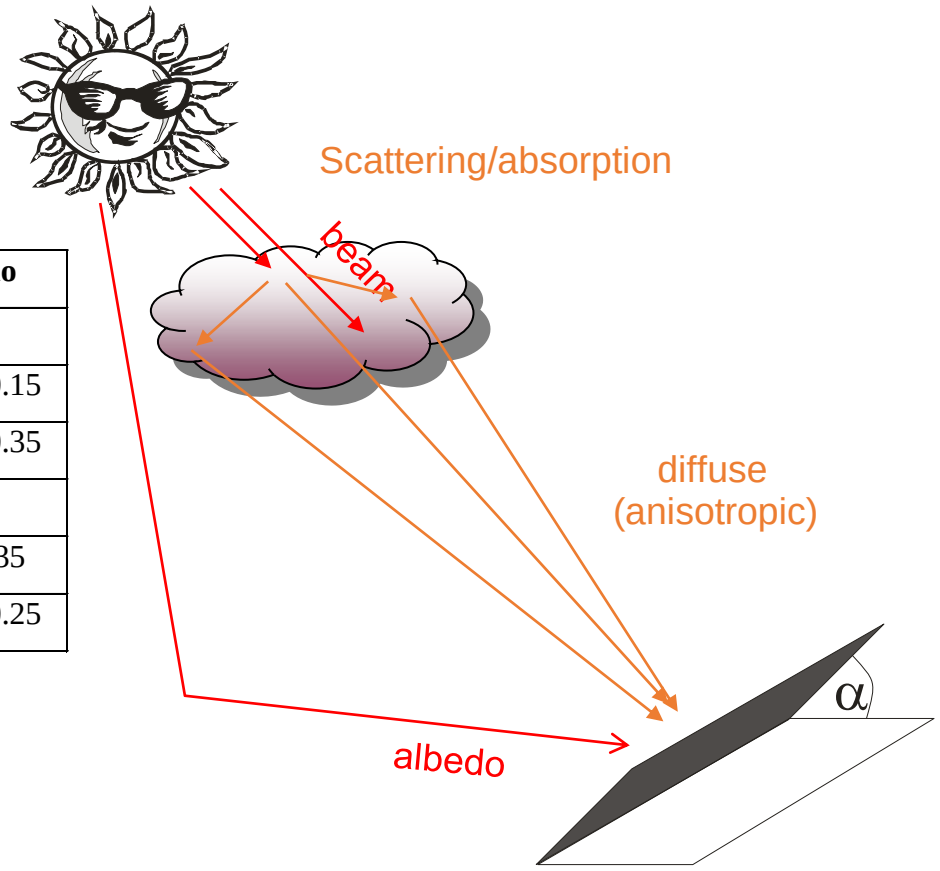
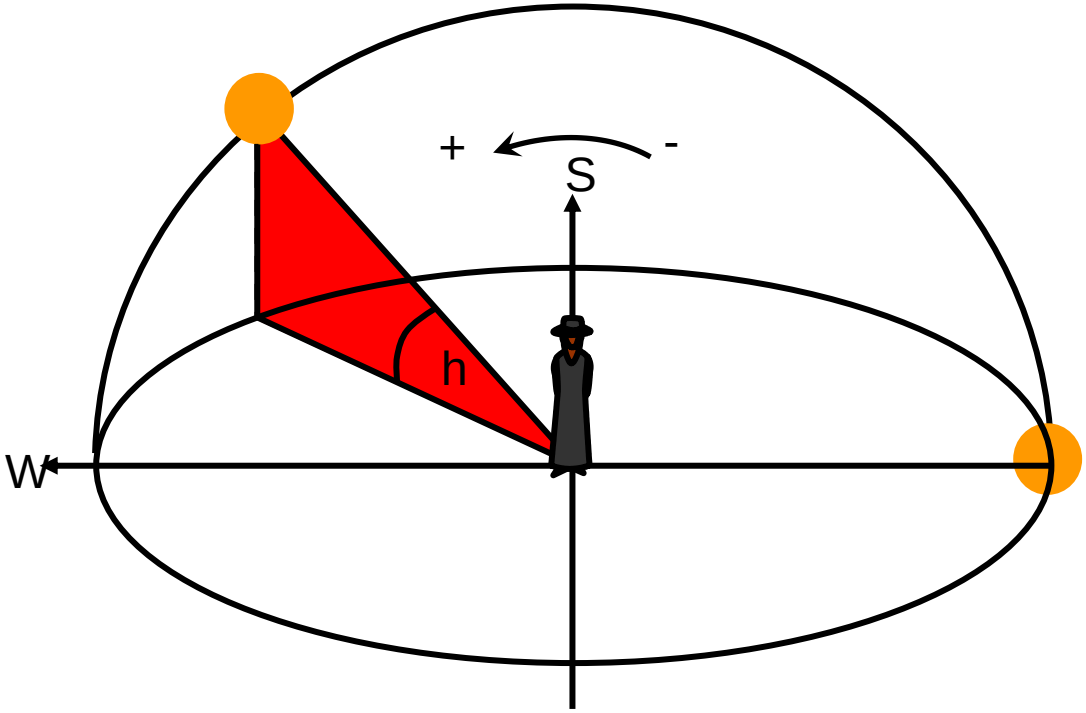


Angles determining the position of the sun

- Elevation h determines the height angle of the Sun
- Azimuth g_S determines the angle between due south and the position of the Sun (northern hemisphere)

Position of the sun

- Horizontal System, Observer in Centre
- Elevation h - height



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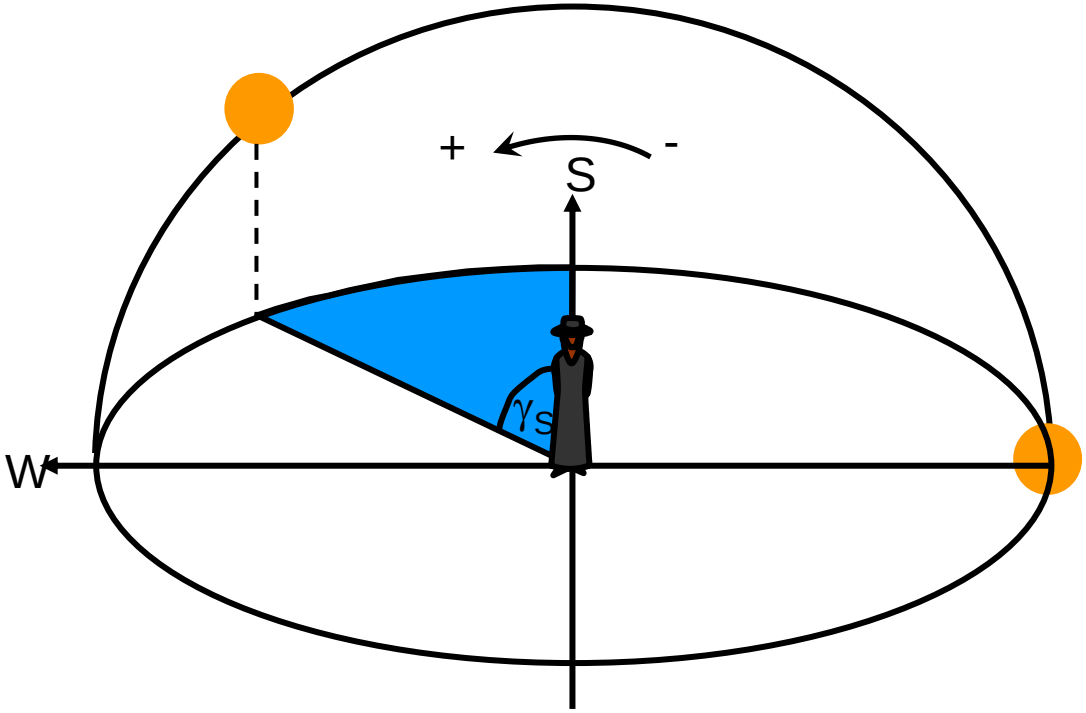
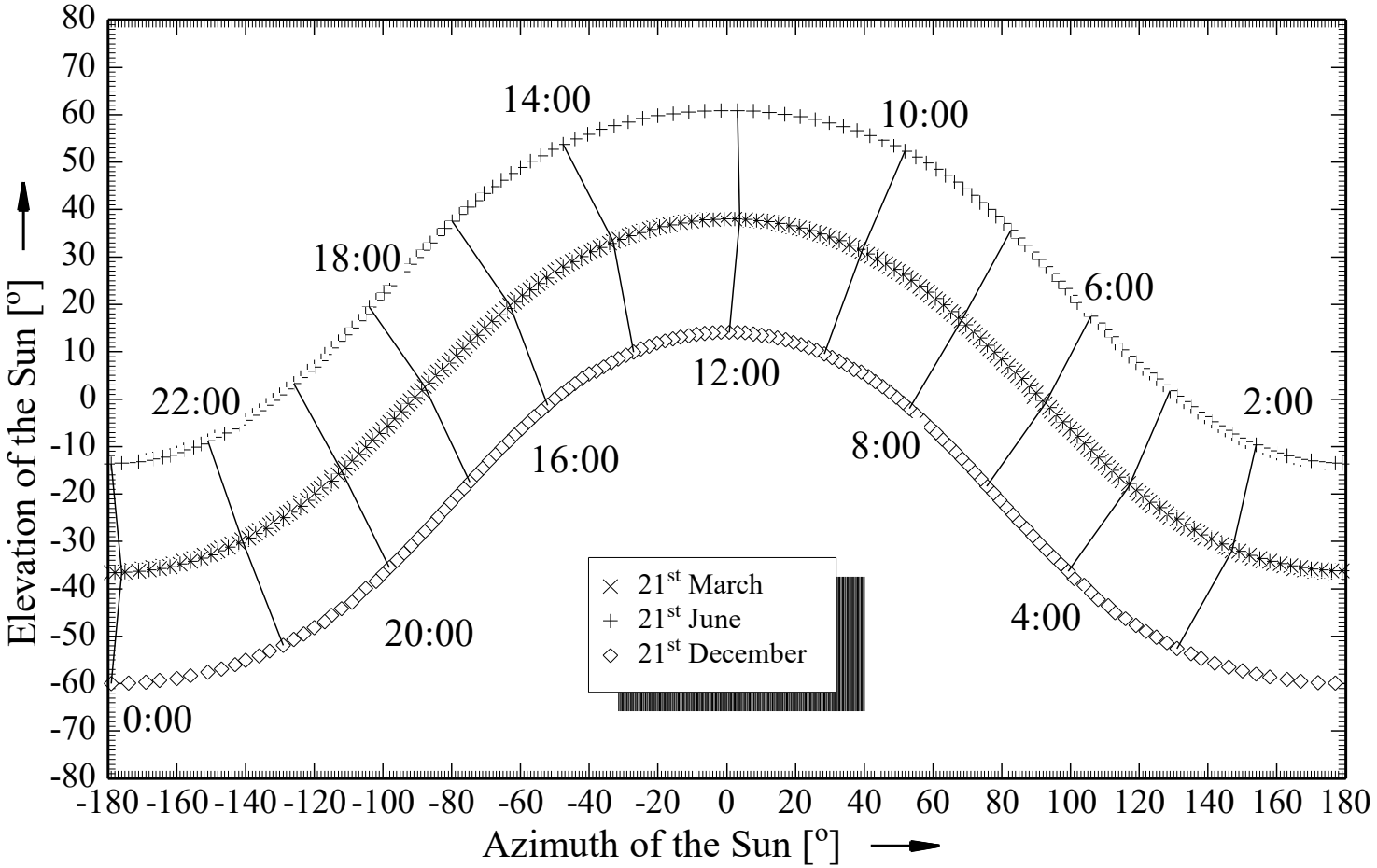
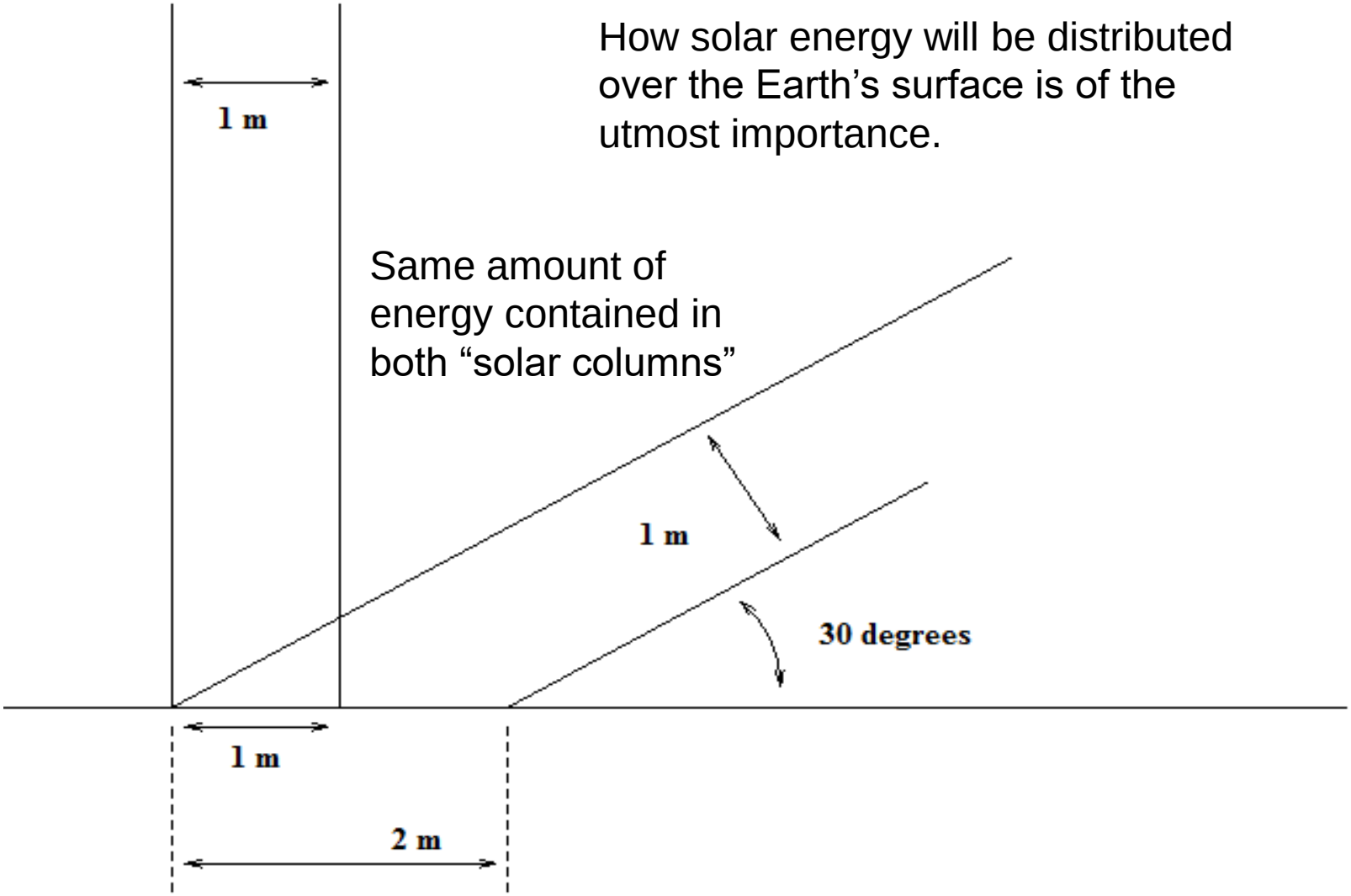


Path of the sun

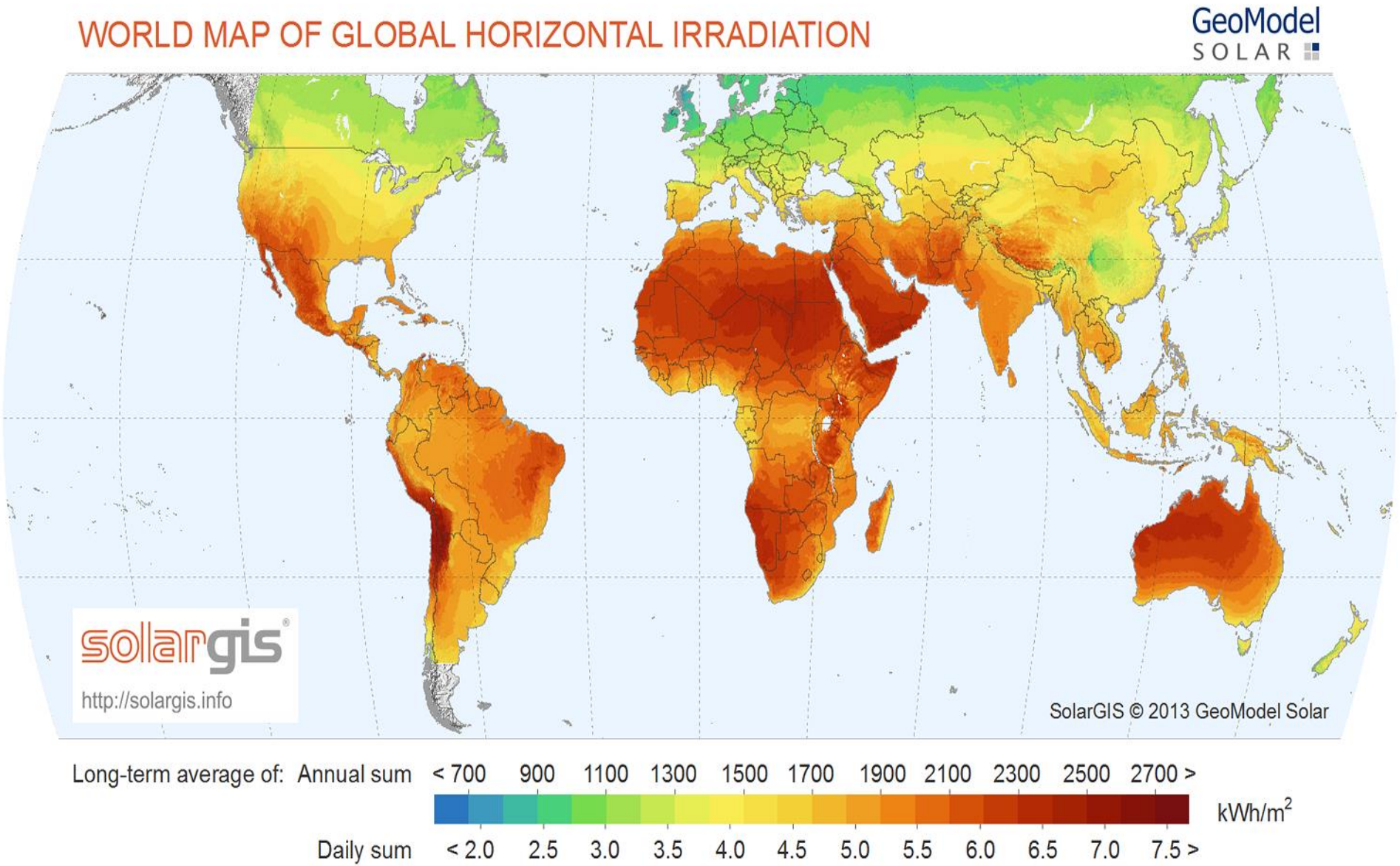


And the main reason for caring is this

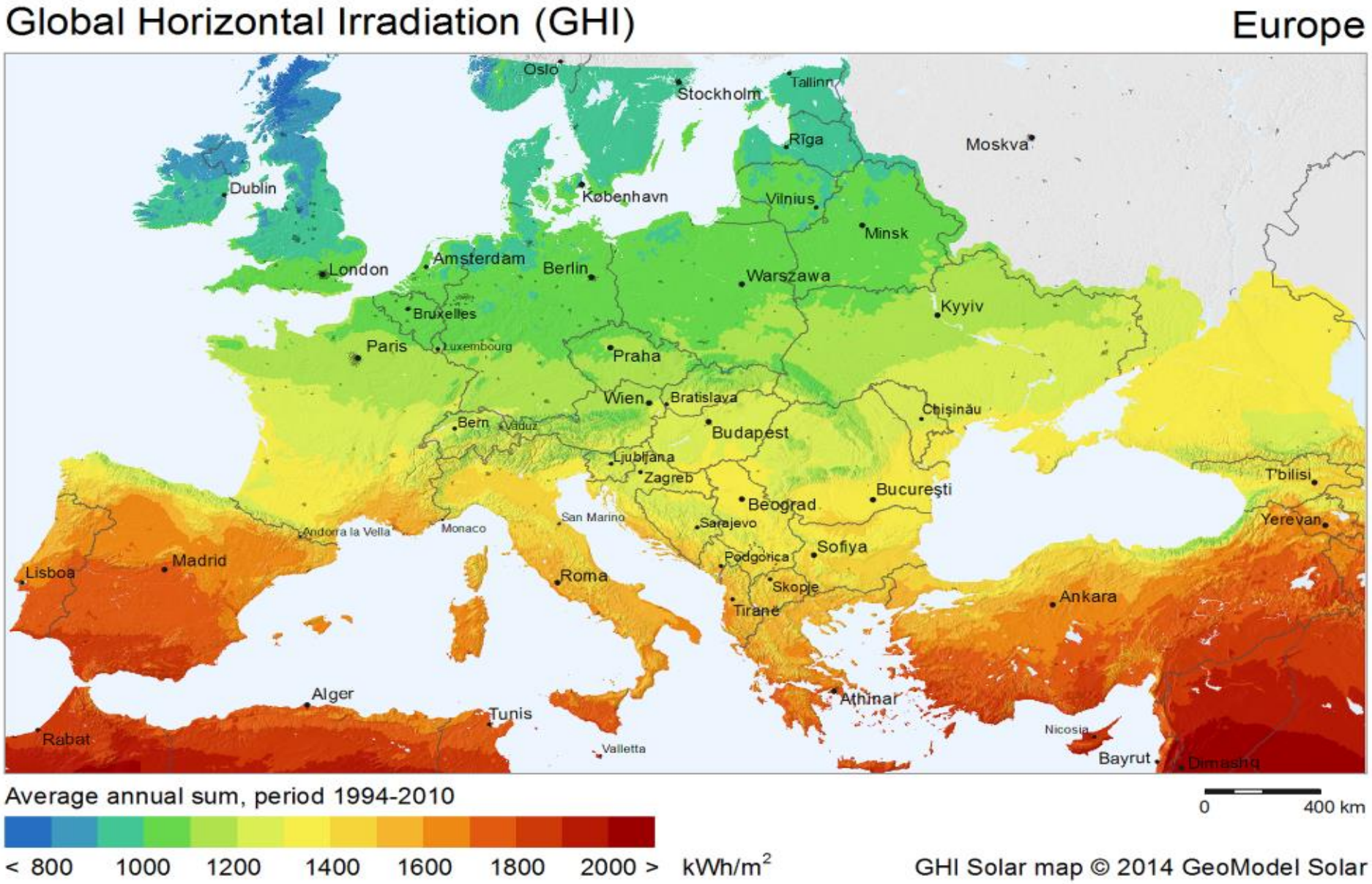
How solar energy will be distributed over the Earth's surface is of the utmost importance.



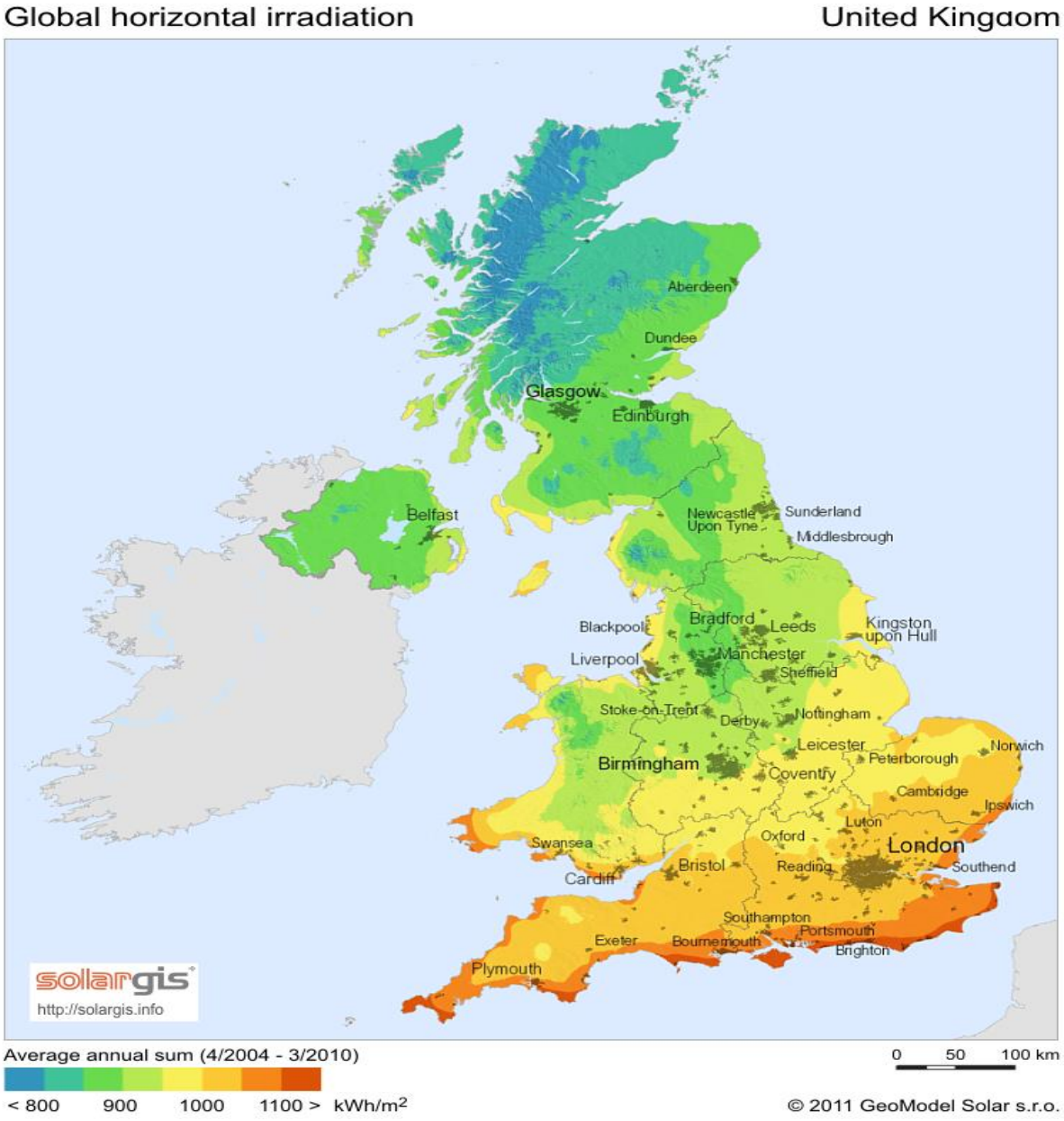
World solar map



Europe Solar map



UK solar map


Global horizontal irradiation
United Kingdom
Aberdeen
Dundee
Glasgow
Edinburgh
Belfast
Newcastle Upon Tyne
Sunderland
Middlesbrough
Blackpool
Bradford
Leeds
Kingston upon Hull
Liverpool
Manchester
Sheffield
Stoke-on-Trent
Derby
Nottingham
Leicester
Norwich
Peterborough
Birmingham
Coventry
Cambridge
Ipswich
Luton
Swansea
Oxford
London
Bristol
Reading
Southend
Cardiff
Southampton
Portsmouth
Exeter
Bournemouth
Brighton
Plymouth
solargis
http://solargis.info
Average annual sum (4/2004 - 3/2010)
< 800
900
1000
1100 >
kWh/m2
0
50
100 km
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Interactive map

http://globalsolaratlas.info/

You also use this
http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#TMY

Measurements

Name	Type of Receiver	Use	Comment
Pyranometer	Thermopile	Outdoor global measurements	Very high accuracy, slow response
Photovoltaic Sensor (Solarimeter)	Solar Cell	Outdoor global measurements	High accuracy, fast response
Reference Cell	Solar Cell	Indoor calibration	
Spectroradiometer	Photodiode	Spectral measurements	Slow, medium accuracy
Campbell Stokes	Cardboard strips	Sunshine hours	Crude
Satellite Photo	Film	Estimation of global irradiation, cloud cover	Limited accuracy

pyranometers

Spectroradiometer