Weather data and solar radiation

MATLAB / Octave files:
`t01ReadWeather.m`
`fReadWeather.m`
`fSolRadTiltSurf.m`

Objectives:

- Obtain weather data from Energy Plus
- Read weather data
- Find solar radiation on a tilted surface
- Visualize and discuss the data

1 Download Octave from

https://www.gnu.org/software/octave/download
and install.

2 Obtain weather data

2.1 Data file from EnergyPlus

Download the weather file with extension .epw from
`https://energyplus.net/weather` for example: `FRA_Lyon.074810_IWEC.epw`

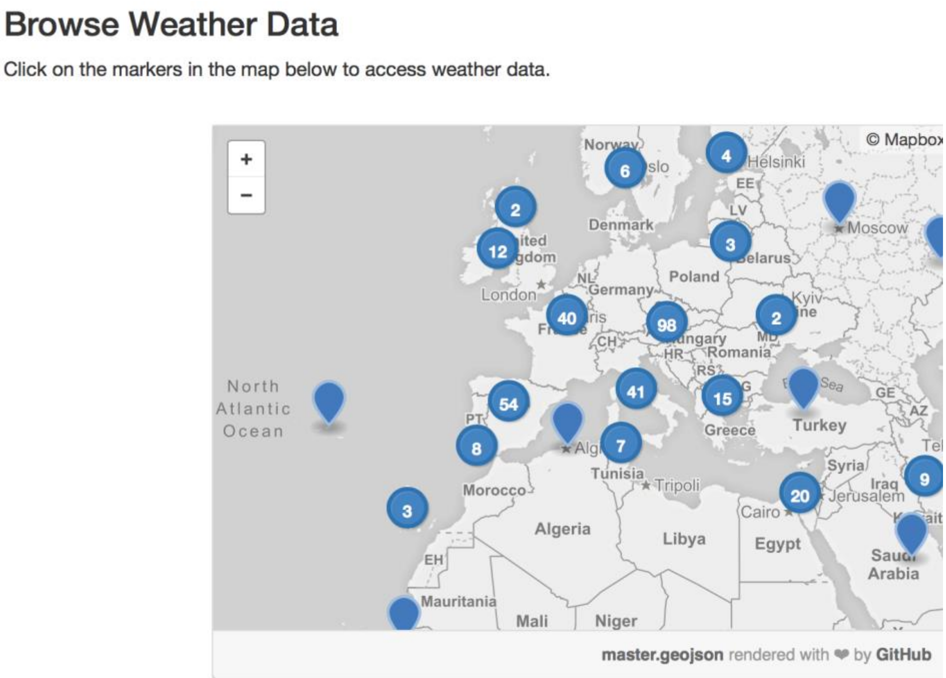
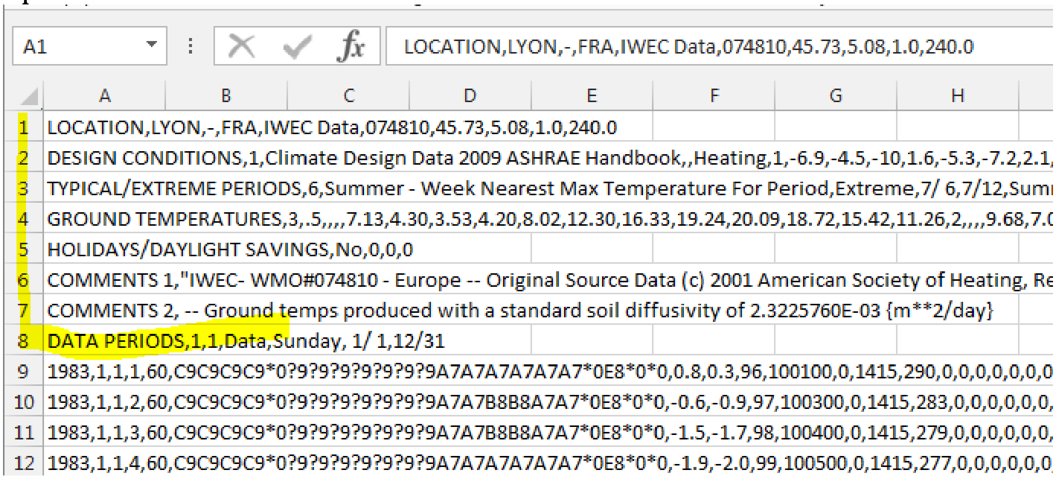


Figure 1 Screenshot of EnergyPlus weather data site: select city

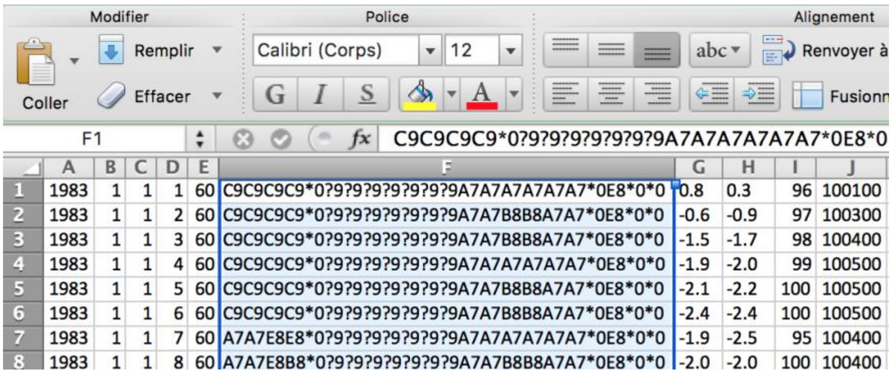
Modify the weather file `.epw` to retain only the data: delete the header and the column F (the 6th column).

For this:

- Save the `.epw` file in the working directory.
- Add the extension `.txt` after `.epw` to obtain `.epw.txt`
- Open this file with a text editor or with Excel and delete the first 8 lines



- Save the file with extension `.csv`
- Open the file `.csv` file with Excel and delete column F.



- Save the file as `.csv`

2.2 EnergyPlus weather data file description

See details at page 35/144 of EnergyPlus documentation.

N1, \field Year
N2, \field Month
N3, \field Day
N4, \field Hour
N5, \field Minute
A1, \field Data Source and Uncertainty Flags
N6, \field Dry Bulb Temperature\units C
N7, \field Dew Point Temperature\units C

N8, \field Relative Humidity
N9, \field Atmospheric Station Pressure\units Pa
N10, \field Extraterrestrial Horizontal Radiation\units Wh/m2
N11, \field Extraterrestrial Direct Normal Radiation\units Wh/m2
N12, \field Horizontal Infrared Radiation Intensity\units Wh/m2
N13, \field Global Horizontal Radiation\units Wh/m2
N14, \field Direct Normal Radiation\units Wh/m2
N15, \field Diffuse Horizontal Radiation\units Wh/m2

2.3 Read and visualize weather data

```
MATLAB/Octave::
Toolbar:: Tab Current Directory : chose your working directory

Editor:: File \ Open: t01ReadWeather.m

Command Window::
>> t01ReadWeather
```

3 Numerical experiments and discussion

Change the start day and duration period. For example, in order to load data from June, in lines 5 and 6 use:

```
5  from = 6*30*24;     % start time: from 24 Jan.
6  period = 10*24;     % simulation period: in hours
```

Modify the orientation and the tilt of the surface.

```
B = 90; % slope (tilt) angle in deg: [0 180]; 90-vertical; >90-downward facing
Z = 0;  % local latitude in deg: [-90 90], north positive
L = 45; % local latitude in deg: [-90 90], north positive
albedo = 0.2; % albedo of ground = 0.2
[PhiDir, PhiDif, PhiRef] = fSolRadTiltSurf(month, day, hour, minute,...
    RadNDir, RadHDif, B, Z, L, albedo);
```

Discuss the results for different periods of time of the year (winter, mid-season, summer) and for different tilts and orientations of the surface. Compare and explain the differences for:

- direct and the diffuse radiation;
- winter, mid-season and summer.

4 Solar radiation on a tilted surface

4.1 Definitions

The following definitions are used [EnergyPlus, Duffie and Backman (2013)]:

Direct Normal or Beam Radiation G_b. Amount of solar radiation in $\mathrm{Wh/m^2}$ received directly from the solar disk on a surface perpendicular to the sun's rays, during the number of minutes preceding the time indicated.

Diffuse Radiation G_d**.** The solar radiation received from the sun after its direction has been changed by scattering by the atmosphere. Diffuse radiation is referred to in some meteorological literature as sky radiation or solar sky radiation; the definition used here will distinguish the diffuse solar radiation from infrared radiation emitted by the atmosphere.

Total Solar Radiation. Total amount of direct and diffuse solar radiation in $\mathrm{Wh/m^2}$ received on a horizontal surface during the number of minutes preceding the time indicated. The most common measurements of solar radiation are total radiation on a horizontal surface, often referred to as global radiation on the surface.

Solar Time. Time based on the apparent angular motion of the sun across the sky with solar noon the time the sun crosses the meridian of the observer

4.2 Definition of angles

ϕ **Latitude**: the angular location north or south of the equator, north positive; $-90° \leq \phi \leq 90°$.

δ **Declination**: the angular position of the sun at solar noon (i.e., when the sun is on the local meridian) with respect to the plane of the equator, north positive; $-23.45° \leq \delta \leq 23.45°$.

β **Slope**: the angle between the plane of the surface in question and the horizontal; $0° \leq \beta \leq 180°$. $\beta > 90°$ means that the surface has a downward-facing component.

γ **Azimuth**: the deviation of the projection on a horizontal plane of the normal to the surface from the local meridian, with zero due south, east negative, and west positive; $-180° \leq \gamma \leq 180°$.

ω **Hour angle**: the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour; morning negative, afternoon positive:

$$\omega = 15(hour + \frac{minute}{60} - 12)$$

where $hour{:}minute$ is the solar time.

θ **Incidence**: the angle between the beam radiation on a surface and the normal to that surface.

θ_z **Zenith angle of the sun**: the incidence angle for a horizontal surface; $0° \leq \theta_z \leq 90°$.

Declination angle (Duffie and Beckman 2013):

$$\delta = 23.45° \sin\left(360\frac{284 + n}{365}\right)$$

where n is the day of the year.

The angle of incidence of beam radiation on the surface is:

$$\theta = \text{acos}(\sin\delta\sin\phi\cos\beta - \sin\delta\cos\phi\sin\beta\cos\gamma + \cos\delta\cos\phi\cos\beta\cos\omega + \cos\delta\sin\phi\sin\beta\cos\gamma\cos\omega + \cos\delta\sin\beta\sin\gamma\sin\omega)$$

For horizontal surfaces, $\beta = 0$, the angle of incidence is the zenith angle of the sun, θ_z, must be between 0° and 90° when the sun is above the horizon:

$$\theta_z = \text{acos}(\cos\phi\cos\delta\cos\omega + \sin\phi\sin\delta)$$

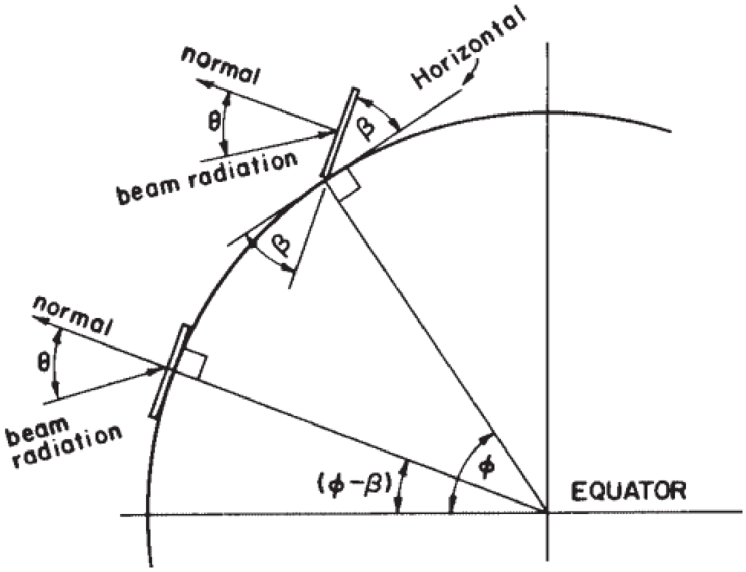


Figure 2 Latitude, ϕ, slope, β and incidence, θ, angles

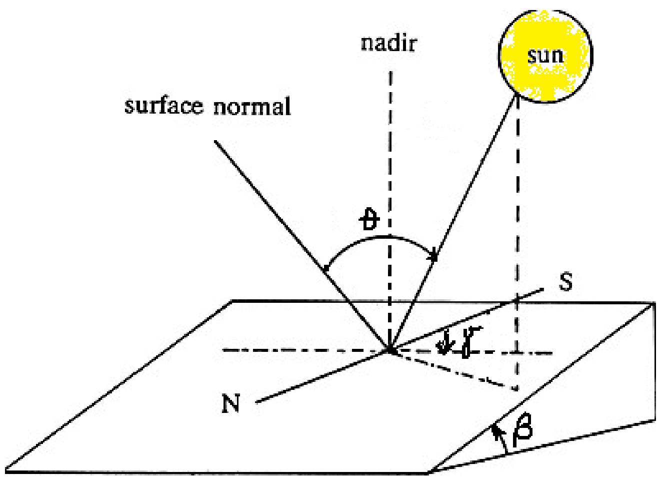


Figure 3 Azimuth, γ, slope, β, and incidence, θ, angles

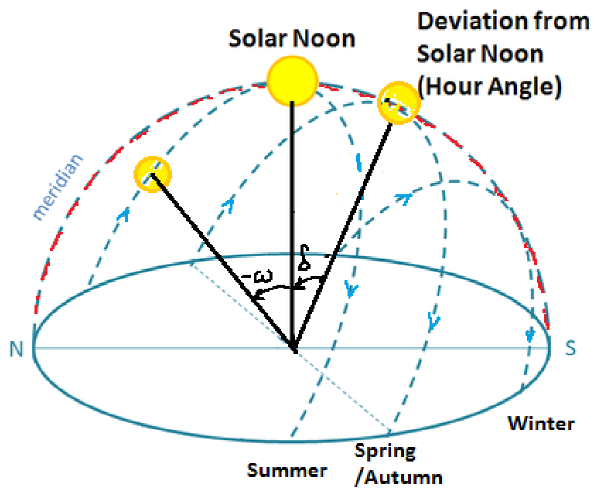


Figure 4 Hour, ω, and declination, δ, angles

4.3 Ratio of beam radiation on tilted surface to that on horizontal surface

The most commonly available data are total radiation for hours or days on the horizontal surface, G_b , whereas the need is for beam, $G_{b,T}$, and diffuse radiation on the tilted plane. The geometric factor R_b, the ratio of beam radiation on the tilted surface to that on a horizontal surface at any time, can be calculated exactly by:

$$R_b = \frac{G_{b,T}}{G_b} = \frac{G_{b,n}\cos\theta}{G_{b,n}\cos\theta_z} = \frac{\cos\theta}{\cos\theta_z}$$

where $G_{b,n}$ is the radiation on a plane normal to the direction of propagation.

The radiation on a tilted surface is then:

$$G_{b,T} = R_b G_b$$

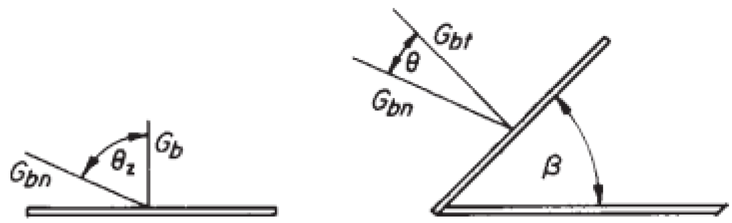


Figure 5 Beam radiation on horizontal and tilted surfaces

5 References

1. J. A. Duffie, W. A. Beckman (2013) Solar Engineering of Thermal Processes, 4th ed., Wiley
2. BigLadder Software (2016) EnergyPlus Weather File (EPW) Data Dictionary
3. EnergyPlus Documentation, page 35/144: weather file description