

The script *pdf.py* needs the Python interpreter and some mathematic libraries to be installed on the system. All the necessary bundles are also provided with the program. Next, we describe from the installation process to the operation with the script.

## 1. INSTALLATION NOTES

Supposing a Windows environment, the installation is quite straightforward. First bundle to be installed is the Python interpreter, just by double-clicking on the *python-2.5.1.msi* file and accepting the default installation directory (C:\Python25) (recommended). Then, some Windows utilities for the interpreter (*pywin32-209.1.win32-py2.5.exe*) can be installed. Although it is not strictly necessary, is recommended since it also includes a nice GUI (Graphical User Interface). The next steps deal with the necessary scientific libraries that complement the Python interpreter. These bundles must be installed in the usual way (just double-clicking) in the next order: *numpy-1.0.1.win32-py2.5.exe*, *matplotlib-0.90.0.win32-py2.5.exe* and *scipy-0.5.2.win32-py2.5.exe*.

It is also recommended to include the Python interpreter in the path of the system. This can be carried out by following *Start/Control Panel/System/Advanced Options/Environment Variables*. Then, we edit the *PATH* variable of the system and add at the end the installation directory of the Python interpreter. In the default case, simply adding ‘C:\Python25’ (without quotations).

## 2. SCRIPT DESCRIPTION

The script calculates the probability density functions (hereafter, PDF) of the clearness index, the diffuse fraction and the direct radiation fraction, conditioned to the optical air mass and fit them with the Boltzmann Model described in the section 7. The values of optical air masses for which the PDF is calculated are 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5, ranging a solar height from zenith to about 15 degrees.

The input data are provided in a column-organized text file conformed as follows. The first line holds the longitude and the latitude of the data site. These values are used for determining the clearness index and shift the data to local apparent time. The next row is dedicated to the column headers and the rest of rows will hold the data. The columns order is year, month, day, hour, minute global horizontal solar radiation, diffuse horizontal solar radiation and direct horizontal solar radiation. The year format must be four-digit. From the first five columns the program computes the optical air mass and the extraterrestrial irradiance. Then, it calculates the clearness index using the global measured radiation. The script is intended to use minute-basis data and it must be taken in account than the greater the number of data, the better performance of the fitting model. For example, for debugging purposes a data file with a year of measurements is used. This represents approximately half-million records and therefore, a quarter-million of usable records (after removing the night measurement). An example of the first lines of a possible input file is shown in figure 1. The diffuse and direct fractions are calculated by dividing the diffuse and direct data with the global radiation. The histograms are calculated using 50 bins, or equivalently, a bin width of 0.02. This value can be changed editing the script.

```

-3.62 37.15
YEAR  MONTH DAY HOUR  MINUTE  GLOBAL  DIFFUSE BEAM
1994   1  13 12  57   517.00 112.33  404.68
1994   1  13 12  58   516.00 111.00  405.00
1994   1  13 12  59   516.00 108.33  407.67
1994   1  13 13   0   514.00 108.35  405.65
1994   1  13 13   1   515.00 108.38  406.62
1994   1  13 13   2   510.00 108.40  401.60
1994   1  13 13   3   512.00 108.43  403.57
1994   1  13 13   4   512.00 107.11  404.89
1994   1  13 13   5   515.00 107.14  407.86
1994   1  13 13   6   517.00 105.82  411.18
1994   1  13 13   7   515.00 104.51  410.49
1994   1  13 13   8   511.00 103.20  407.80
1994   1  13 13   9   511.00 103.23  407.78
1994   1  13 13  10   512.00 104.59  407.41
1994   1  13 13  11   510.00 107.31  402.70
1994   1  13 13  12   505.00 107.34  397.66
1994   1  13 13  13   507.00 108.71  398.29

```

Figure 1. Example of the first lines of a possible input data file for *pdf.py*

The measurement time can be provided either as '*local apparent time*' or as '*local standard time*' as described in Section 1.4 in Iqbal (1983). By defaults the script expects '*local apparent times*'.



It is very important to use the option `-L` with the local standard meridian when the data are referred to local time.

By means of the flag `-g`, the script will present the results in three windows, (clearness index, diffuse fraction and direct fraction), with a graph area for each optical air mass with the PDF histogram and the fitting curves. The values of the Boltzmann Model parameters are written down in an output text file.

```

F:\proyectos\Springer\software| python pdf.py --help
Usage: pdf.py [options]

Options:
-h, --help            show this help message and exit
-i FILE, --infile=FILE input filename
-o FILE, --outfile=FILE output filename for the fitting coefficients
-L LST, --LST=LST     data in local standard time as described in Iqbal, M.,
                        1983, 'An introduction to solar radiation', Canada:
                        Academic Press, ISBN 0-12-373752-4, Section 1.4 for
                        this standart meridian
-g, --graph           Shows the probability density function for each
                        optical mass

```

Figure 2. Help information provided by the program.

### 3. SCRIPT OPERATION

The script should be run from a command line prompt for a proper operation. We will suppose that the Python interpreter is included in the system path as explained in section 1. To open a command prompt, just go to *Start/Run...*, type '*cmd*' (without quotations) and accept. Using the command *cd* (type *help cd* for information) go to the directory where the *pdf.py* script is. A coarse help lines (figure 2) on using the program are provided by typing *python pdf.py --help* or when an erroneous call is introduced.

The option *-i* is used to indicate what is the input data file. The rest of options are optional: the *-o* option indicates the text file to write the parameters of the fitting models for each optical air mass. The *-L* option allows using times referred to the local meridian or the local standard meridian, as explained in Iqbal (1983), section 1.4. Finally, the option *-g* will show the graph windows.

It is worth to note that the fitting process starts with a guess value for each parameter of the model. The set of guess values depends on the shape of the PDF that, as is known, is influenced by the local features of the sites. For this reason, it might be necessary a re-adjusting of these guess values in the script depending on the dataset used. The guess values in the script are initialized to those proposed in the section 7 for Armilla.

```
02/41/07 20:41:55
sample.tab: found 251517 utilizable records
Bin size: 0.02

Pdf for clearness index:
-----
  m          A1      lambda1      kt01          A2      lambda2      kt02
-----
1.0      1.599      59.439      0.726      -0.599      -3.931      0.392
1.5      1.421      44.715      0.712      -0.421     -11.228      0.327
2.0      1.416      44.097      0.694      -0.416     -11.351      0.306
2.5      1.469      30.172      0.648      -0.469     -13.771      0.263
3.0      1.484      45.408      0.618      -0.436     -13.793      0.250
3.5      1.488      25.225      0.584      -0.488     -14.070      0.212
-----

Pdf for diffuse fraction:
-----
  m          A      lambda      kd0      beta
-----
1.0     -0.048     847.677      1.251     811.080
1.5      0.047     237.364      0.078    -115.636
2.0      0.069     234.595      0.086    -112.730
2.5      0.061     172.084      0.107     -83.340
3.0      0.081     120.578      0.126     -57.899
3.5      0.068      95.386      0.154     -47.247
-----

Pdf for direct fraction:
-----
  m          A      lambda      kb0      beta
-----
1.0      1.689      8.289      0.920     168.768
1.5      1.601      6.161      0.902     113.821
2.0      1.529      9.145      0.894     112.848
2.5      1.422      9.538      0.329     110.001
3.0      1.364     10.366      0.235     108.758
3.5      1.306     10.499      0.183     108.378
-----
```

Figure 3. Output file with the parameters values for each probability density function.

#### 4. EXAMPLE OF EXECUTION

For a better understanding of the operation we will follow a simple example. Let suppose that the directory *F:\PDF* contains the script file *pdf.py* and the input data file *sample.tab*. In such case, the command

```
F:\PDF\>python pdf.py -i sample.tab -o BMparams.txt -L 0 -g
```

will calculate the fitting parameters for the data compiled in the file *sample.tab* and will write them into the file *BMparams.txt* (figure 3) in the same directory. The progress of the work can be follow by a progress bar (figure 4) because usually the size of the input file is quite large and the operation is slow. In this example, the time values are corrected to the '*local standard time*' using the option *-L* with the local standard meridian 0. Finally, the option *-g* shows the output plots (figure 5). With the option *-s0.01* we could set a bin size of 0.01. Because this option is not included in the called, the bin size will be 0.02.

```
F:\PDF|▶ python pdf.py -i sample.tab -o BMparams.txt -L 0 -g
Site longitude      :  -3.62
Site latitude       :  37.15
Standard meridian   :   0.00

Found 251517 utilizable diurnal records.

Calculating the clearness index and the optical mass...

-----
|  20%  40%  60%  80% 100%|
|#####|
```

Figure 4 Information on screen during the script operation.

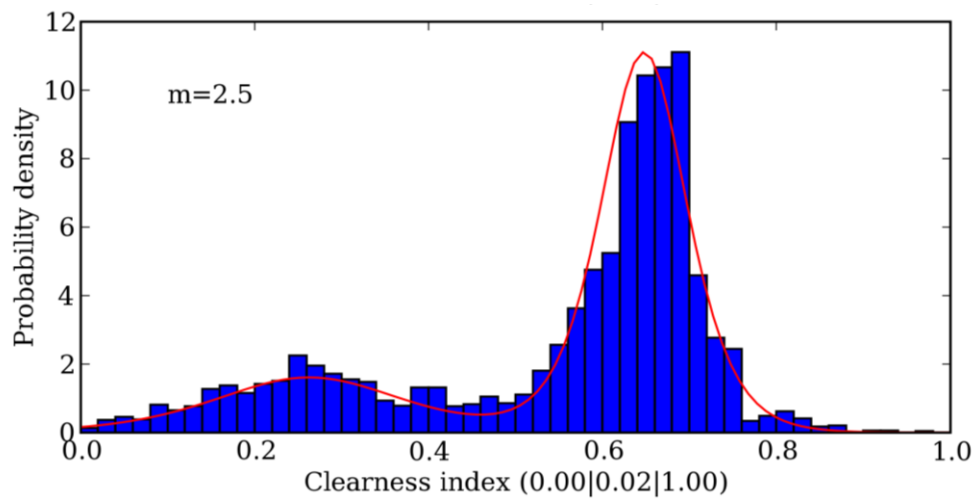
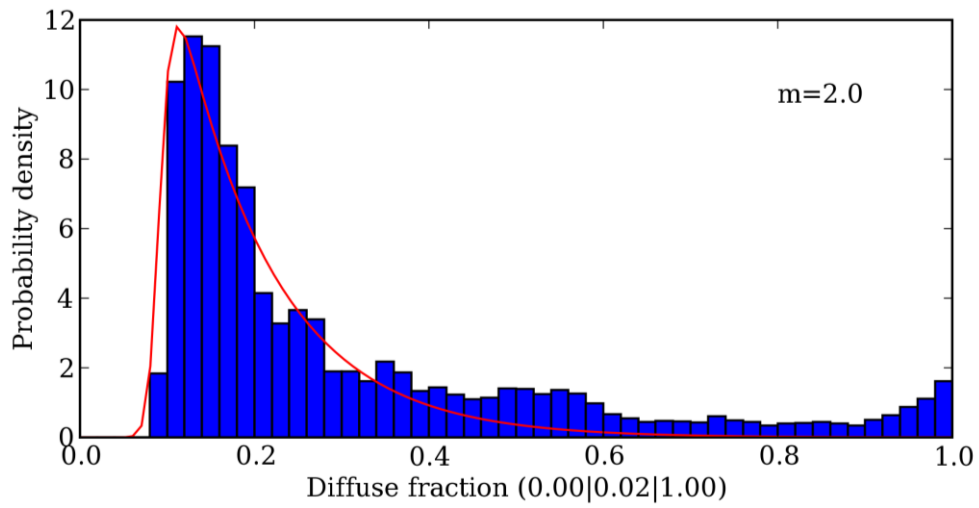
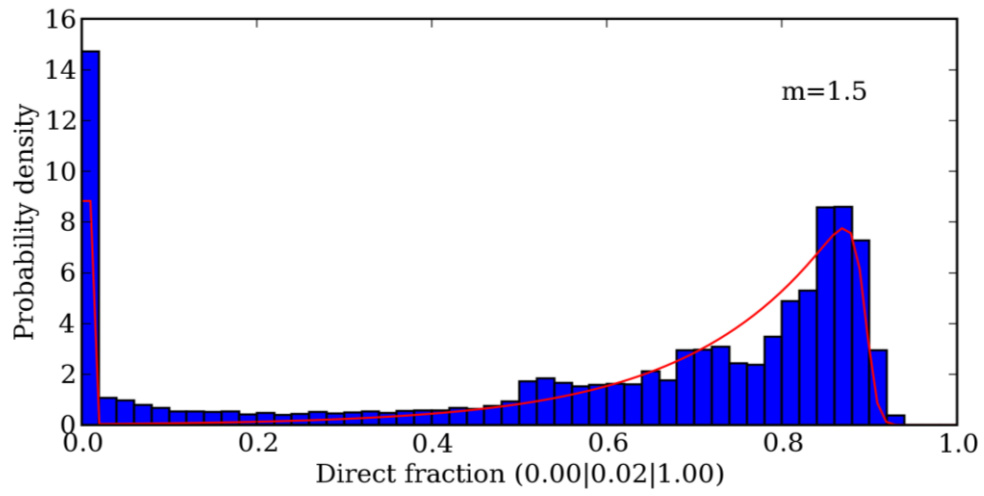
#### 5. BIBLIOGRAPHY AND REFERENCES

Tovar, J., Olmo, F.J., Alados-Arboledas, L., 1998, 'One-minute global irradiance probability density distributions conditioned to the optical air mass', *Solar Energy*, Vol. 62, pp. 387-393

Tovar, J., Olmo, F.J., Alados-Arboledas, L., 1998, 'One-minute kd and kb probability density distributions conditioned to the optical air mass', *Solar Energy*, Vol. 62, pp. 387-393

Iqbal, M., 1983, 'An introduction to solar radiation', Canada: Academic Press, ISBN 0-12-373752-4.

Langtangen, H.P., 2006, 'Python scripting for computational science', 2<sup>nd</sup> Edition, Springer-Verlag, ISBN 3-540-29415-5



**Figure 5.** Example of graphical outputs for the probability density function of the direct fraction (up), diffuse fraction (middle) and clearness index (bottom), for different optical air masses. The blue bars are the relative frequency of the input data and the solid red line is the fitting curve.