where p_1 and p_2 are the adjusted parameters for which values are 4.46×10^{-4} and -1.19×10^{-4}, respectively. The corresponding value of the so-called correlation coefficient, R^2, is greater than 0.98, indicating that equations (20.50) and (20.51) adjust very well to the simulated values. This way, the results of a rather complex calculation, involving a lot of tedious steps, can be described by means of two simple mathematical expressions. Apart from simplicity and elegance, all the information has been condensed into just four numbers and an equation that have the advantage of having a continuous slope, which can be useful in many calculations. It is worth mentioning that these equations can also be used to calculate the value of $G_{dy}(\beta_{opt})$ from the data corresponding to the horizontal surface, which is the most usually available information.

Example: Estimation of the optimal tilt angle and the corresponding yearly irradiation in Sapporo-Japan knowing the latitude, $\phi = 43°$, and the annual average of the daily global horizontal irradiation, $G_{dy}(0) = 3220$ Wh/m^2. The solution is

$$\text{Equation (20.50)}, \phi = 43° \Rightarrow \beta_{opt} = 33.37°$$

$$\text{Equation (20.51)}, \beta = 0° \Rightarrow G_{dy}(0)/G_{dy}(\beta_{opt}) = 0.8526$$

$$\Rightarrow G_{dy}(\beta_{opt}) = 1.1729 \times G_{dy}(0) = 3776 \text{ Wh/m}^2.$$

The total yearly irradiation is $365 \times G_{dy}(0) = 1379$ kWh/m^2.

It is worth mentioning that a more careful calculation, using the 12 values of the monthly mean irradiation and following the procedure described in Figure 20.16, would lead to $G_{dy}(\beta_{opt}) = 3663$ Wh/m^2. This means, that the error associated to equation (20.51) is below 3%.

Attempting to help in the following discussion, Table 20.5 presents the results of a detailed simulation exercise devoted to the calculation of the annual radiation availability on horizontal surfaces, optimally tilted fixed surfaces and several types of tracking surfaces. The exercise has been extended to 30 different places distributed around the World. The hope is that the readers could find here a relatively similar location, both in latitude and clearness index, to the location of their interest. The yearly means of the daily global horizontal irradiation, $G_{dy}(0)$, can be obtained by multiplying the corresponding values of the extraterrestrial radiation and the clearness index. (column 3 × column 4). Then, these horizontal $G_{dy}(0)$ values are used as reference for the irradiation availability in all the other considered surfaces. In particular, column 8 of this table gives the ratio between the global irradiation on a fixed and optimally tilted surface to the global horizontal irradiation, $G_{dy}(\beta_{opt})/G_{dy}(0)$. Hence, the irradiation on the optimally tilted surface is given by the product (column 3 × column 4 × column 8).

20.9.1 Fixed Surfaces

The integration of PV generators in buildings, presently in vogue in many industrialised countries, led to the use of a large range of different orientations and tilt angles. PV module orientations from east to west, and tilt angles from horizontal to vertical are found in practise. Then, it is worth extending the previous exercise to surfaces other than those