Direct, diffuse and total solar radiation data set in La Guajira, Magdalena and Cesar departments -Colombia

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**Abstract**

This article aims to show direct, diffuse, and total solar radiation in the departments of La Guajira, Magdalena, and Cesar, located on the Caribbean coast of Colombia. In addition, data on climatic variables such as temperature, pressure, and relative humidity measured through different sensors located in these meteorological stations are presented. The data obtained by these stations correspond to measurements from 1993 to 2013 allowed the estimation of the parameters of the total, direct and diffuse solar radiation for each department, by mean of the Bird and Hulstrom model and parameterizations of the Mächler and Iqbal model. In addition, five climatological scenarios that could occur using these data were calculated.

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Specifications Table

| Subject area          | Renewable energy                                      |
|-----------------------|-------------------------------------------------------|
| More specific subject area | Solar field, solar energy                             |
| Type of data          | Raw, Graphs, figures, tables                         |
| How data was acquired | Pressure sensor Lambrecht Ref. 8121, temperature sensor Siap + Micros Ref. T001-TTEP-N and relative humidity Siap + Micros Ref. T003-TEH-V. |
| Data format           | Raw data and analyzed                                 |
| Parameters for data collection | The data mentioned in this article was administrated by the stations managed by the Hydrology, Meteorology, and Environmental Studies Institute (IDEAM). |
| Description of data collection | The data was collected through the sensors in the weather stations. |
| Data source location  | Caribbean region in Colombia, Departments of La Guajira, Magdalena and Cesar. |
| Data accessibility    | Repository name: Mendeley data: https://data.mendeley.com/datasets/hytc559th51 |
| Data identification number | 10.17632/hytc559th51 |
| Related research article | M. Vanegas, O. Churio, G. Valencia, E. Vilicaña, and A. Ospino, “Calculation of total, direct and diffuse radiation, through the atmospheric transmissivity in the departments of Cesar, La Guajira and Magdalena (Colombia),” Revista Espacios, vol. 38, no. 7, 2017 [1]. |

Value of the Data

- The data provided in this article can be used as a starting point for further research on the behavior of solar radiation in the country, specifically in the Caribbean region of Colombia.
- The raw data presented can be used for the validation of new irradiation calculation models, either empirical or through neural networks.
- These data can be used to make a comparative analysis of solar potential with respect to different regions of the world.

1. Data Description

The data shown in this article are climatic measurements obtained from the stations located in the departments of La Guajira, Magdalena, and Cesar (Colombia). They were obtained from daily averages for each station, from which the direct (IDH), diffuse (IdH) and total (ITH) solar radiation data for different atmospheres were calculated using the Bird and Hulstrom model [2]. This model makes it possible to quantify the different atmospheric transmittances (τ) that are required for the calculation of radiation using the Angström turbidity coefficient (β). This coefficient allows analyzing radiation in different types of atmosphere: (β = 0.0) extremely clean, (β = 0.1) clear, (β = 0.2) medium, (β = 0.3) cloudy, and (β = 0.4) very cloudy. To complete the missing data, it was necessary to apply an interpolation of the available measures as described in Fig. 1. Therefore, daily averages of temperature and humidity were generated for each location in the departments under study.

The average climatic variables for each department are presented in Table 1 (Magdalena), Table 2 (La Guajira), and Table 3 (Cesar). Besides, the monthly trends in temperature and humidity in these places are presented in Fig. 2 (Magdalena), Fig. 3 (La Guajira), and Fig. 4 (Cesar).

The data set is completed with the behavior of direct, diffuse and total solar radiation in the study departments considering the atmospheres presented in Fig. 5 for t(0.0), in Fig. 6 for t(0.1), in Fig. 7 for t(0.2), in Fig. 8 for t(0.3), and in Fig. 9 for t(0.4), based on data collected for 20 years every day. This collection process allowed us to determine the monthly behavior in every
Fig. 1. Flowchart for the treatment of meteorological data.

Table 1
Climate variables for the weather stations in the Magdalena department.

| No | Name               | Elevation (msnm) | Pressure (Pa) | HR\(^*\) (%) | T\(^{\circ}\) (°C) |
|----|--------------------|------------------|---------------|--------------|-------------------|
| 1  | Apto Simón Bolívar| 4                | 101278.5      | 76.1         | 28.3              |
| 2  | Prado Sevilla      | 18               | 101115.8      | 78.2         | 26.8              |
| 3  | La ye              | 20               | 101092.6      | 75.4         | 28.9              |
| 4  | Padelma            | 20               | 101092.6      | 79.5         | 25.4              |
| 5  | Media Luna         | 20               | 101092.6      | 79.9         | 26.6              |
| 6  | Los Álamos         | 25               | 101034.6      | 79.9         | 28.2              |
| 7  | Tayrona            | 30               | 100976.6      | 87.6         | 26.4              |
| 8  | El Seis            | 50               | 100745.1      | 75.2         | 26.9              |
| 9  | Alto de Mira       | 1080             | 89509.9       | 92.3         | 209               |

\(^*\): relative humidity.
\(^{\circ}\): temperature.
Table 2
Climate variables for the weather stations in the La Guajira department.

| No. | Name              | Elevation (msnm) | Pressure (Pa) | HR∗ (%) | T** (°C) |
|-----|-------------------|------------------|---------------|----------|----------|
| 1   | Manaure           | 1                | 101313.4      | 73.1     | 28.7     |
| 2   | Pto. Bolívar      | 10               | 101208.7      | 74.2     | 28.4     |
| 3   | Matitas           | 20               | 101092.6      | 80.9     | 27.6     |
| 4   | Rancho Grande     | 50               | 100745.1      | 65.8     | 27.7     |
| 5   | La Mina           | 80               | 100398.7      | 71.6     | 28.3     |
| 6   | Nazareth          | 85               | 100341.1      | 81.3     | 27.2     |
| 7   | Carraipía         | 118              | 99961.7       | 78.3     | 27.3     |
| 8   | Camp. Intercor    | 122              | 99915.8       | 72.7     | 28.0     |
| 9   | Urumita           | 255              | 98401.8       | 68.4     | 27.7     |

∗ : relative humidity.
** : temperature.

Table 3
Climate variables for the weather stations in the Cesar department.

| No. | Name                | Elevation (msnm) | Pressure (Pa) | HR∗ (%) | T** (°C) |
|-----|---------------------|------------------|---------------|----------|----------|
| 1   | Chiriguaná          | 40               | 100860.8      | 74.3     | 26.8     |
| 2   | Guaymaral           | 50               | 100745.1      | 60.5     | 28.5     |
| 3   | Hda. La Guaira      | 50               | 100745.1      | 76.1     | 28.5     |
| 4   | Col. Agro. Pailitas | 50               | 100745.1      | 71.7     | 25.2     |
| 5   | Villa Rosa          | 70               | 100514.0      | 66.4     | 27.8     |
| 6   | Centenario Hda      | 100              | 100168.4      | 76.4     | 28.1     |
| 7   | La Llana            | 120              | 99938.7       | 85.4     | 27.3     |
| 8   | Apto Alfonso López  | 138              | 99732.4       | 60.0     | 19.4     |
| 9   | Socomba             | 170              | 99366.7       | 76.0     | 27.9     |
| 10  | Motilonia Codazzi   | 180              | 99252.7       | 69.0     | 27.6     |
| 11  | El Rincón          | 350              | 97334.5       | 76.5     | 26.3     |
| 12  | San José de Oriente | 850             | 91904.8       | 79.5     | 24.9     |

∗ : relative humidity.
** : temperature.

Table 4
Information of each column in the raw dataset.

| Symbol | Description                          | Symbol | Description                          |
|--------|--------------------------------------|--------|--------------------------------------|
| Max    | Maximum daily temperature (°C)       | R7     | Relative humidity at 7:00 a.m. (%)   |
| Min    | Minimum daily temperature (°C)       | R13    | Relative humidity at 1:00 p.m. (%)   |
| Max-Min| Temperature difference, (°C)         | R19    | Relative humidity at 7:00 p.m. (%)   |
| T-7    | Dry bulb temperature at 7:00 a.m. (°C)| Mean   | Mean daily relative humidity, (%)    |
| T-13   | Dry bulb temperature at 1:00 p.m. (°C)| P7     | Pressure at 7:00 a.m. (inHg)        |
| T-19   | Dry bulb temperature at 7:00 p.m. (°C)| P13    | Pressure at 1:00 p.m. (inHg)        |
| Mean   | Mean daily dry bulb temperature, (°C)| P19    | Pressure at 7:00 p.m. (inHg)        |
| T7     | Wet bulb temperature at 7:00 a.m. (°C)| Mean   | Mean daily pressure (inHg)          |
| T13    | Wet bulb temperature at 1:00 p.m. (°C)| Tr7    | Dew temperature at 7:00 a.m.        |
| T19    | Wet bulb temperature at 7:00 p.m. (°C)| Tr13   | Dew temperature at 1:00 p.m.        |
| Mean   | Mean daily wet bulb temperature, (°C)| Tr19   | Dew temperature at 7:00 p.m.        |

department considering all of their weather stations, as seen in the original data raw file in the attachment. The information of each column in the raw dataset is presented in Table 4. All raw data is available in https://data.mendeley.com/datasets/hytc559th5/1.
Fig. 2. Temperature and humidity for weather stations in Magdalena from 1993 to 2013, (a) Apto Simón Bolívar, (b) Prado Sevilla, (c) La Ye, (d) Padelma, (e) Media Luna, (f) Los Alamos, (g) Tayrona, (h) El seis, and (i) Alto de Mira.

Table 5

| Measurement               | Precision            |
|---------------------------|----------------------|
| Barometric pressure       | ± 1hPa               |
| Temperature               | 30 to +60°C; ±0.3°C  |
| Relative humidity         | ±0.5% RH             |

2. Experimental Design, Materials and Methods

2.1. Meteorological data

The meteorological stations are located in the departments of La Guajira, Magdalena, and Cesar. These departments are located at the coordinates 11° 14'31" N 74° 12'19" W, 11° 33'N 72° 54'W and 10° 29'00" N 73° 15'00" W. IDEAM provided the temperature, relative humidity, and pressure data required to carry out this study. These measurements were made through the sensors whose specifications are presented in Table 5 and Fig. 10.
Fig. 3. Temperature and humidity for weather stations in La Guajira from 1993 to 2013, (a) Manaure, (b) Pto. Bolivar, (c) Matitas, (d) Rancho Grande, (e) La Mina, (f) Nazareth, (g) Carraipía, (h) Camp. Intercor, and (i) Urumita.

2.2. Method

2.2.1. Bird and Hulstrom model for calculating solar radiation

Taking into account the physical and meteorological conditions of the departments of Magdalena, La Guajira and Cesar, located on the Caribbean coast of Colombia, the Bird and Hulstrom model [2] were used, which is a physical and empirical model based on data and measurements taken in different stations over a certain time. From these measurements, it calculates the atmospheric transmittances that will allow the calculation of total, direct, and diffuse radiation. This model is considered the most suitable because it allows us to identify different coefficients responsible for radiation attenuation due to the presence of different particles in the atmosphere. This model determines direct (IDH) and diffuse (IdH) radiation to know in this way the value of total radiation (ITH).

The direct radiation on a horizontal surface is determined from Eq. (1), considering different cloudiness levels.

\[ I_{DH} = 0.9662 \cdot C_r \cdot \tau_{prom} \cdot \text{sen}(A) \ (\text{W/m}^2) \]  

(1)

where \( \tau_{prom} \) corresponds to the average transmittance calculated from the transmittance by air molecules dispersion (\( \tau_r \)), the transmittance by ozone molecules dispersion (\( \tau_o \)), the transmittance by miscible gasses molecules (\( \tau_g \)), the transmittance by water vapor (\( \tau_w \)), the transmittance by aerosol sprays molecules (\( \tau_a \)), it is also taken into account the daily solar constant which is a function of the Julian day measured in W/m². Also, the 0.9662 belonging to the Eq. (1) is the correction factor adjusted to the wavelength Interval where 96% of the radiation is
concentrated and (A) is the angle of solar altitude. For every one of these transmittance values, different parameters must be considered, which are related in Table 6.

The value ($\beta$) can vary from 0.0 for extremely clean atmospheres, until 0.4 as maximum limit for atmospheres with very high murkiness. Where there are no available measurements, like in this case, the expression proposed by Mächler [3] taken from Buckius and King can be used [4], represented by the Eq. (2), where VIS corresponds to the sky visibility value in km.

$$\beta = 0.55^{\alpha} \cdot \left( \frac{3.912}{\text{VIS}} - 0.01162 \right) \cdot [0.024722 \cdot (\text{VIS} - 5) + 1.132]$$

(2)

Where $\alpha$ indicates the particle size, Mächler suggests as an approximate median value 1.3 $\mu$m, if it is about a natural atmosphere. According to Eq. (2), the values in the parameter $\beta$ will give the visibility in km as shown in Table 7 [4].

According to Global Learning and Observations to Benefit the Environment [5], it is defined that for $\beta=0.0$ the atmosphere is extremely clean in which the sky presents a deep blue color,
Fig. 5. Analysis of direct, diffuse and total radiation at La Guajira, Magdalena and Cesar weather stations from 1993 to 2013 for a $\tau(0.0)$.

Fig. 6. Analysis of direct, diffuse and total radiation at La Guajira, Magdalena and Cesar weather stations from 1993 to 2013 for a $\tau(0.1)$. 

Fig. 7. Analysis of direct, diffuse and total radiation at La Guajira, Magdalena and Cesar weather stations from 1993 to 2013 for a $\tau(0.2)$.

Fig. 8. Analysis of direct, diffuse and total radiation at La Guajira, Magdalena and Cesar weather stations from 1993 to 2013 for a $\tau(0, 3)$.
Fig. 9. Analysis of direct, diffuse and total radiation at La Guajira, Magdalena and Cesar weather stations from 1993 to 2013 for a $\tau(0.4)$.

**Table 6**
Parameters to be taken into account for the values of transmittances.

| Transmission Coefficient | Parameters                                      |
|--------------------------|-------------------------------------------------|
| Air molecules            | Atmospheric mass (ma)                            |
| Miscible gasses          | Atmospheric mass (ma)                            |
| Ozone                    | Thickness of the ozone layer                    |
| Water                    | Amount of precipitable water on site            |
| Aerosols                 | Turbidity Coefficient ($\beta$)                 |

**Table 7**
Sky visibility according to Angström coefficients ($\beta$).

| $\beta$ | 0.0  | 0.1  | 0.2  | 0.3  | 0.4  |
|---------|------|------|------|------|------|
| km      | 340  | 30   | 11   | 7    | <5   |

unusual situation in Earth, so for this case of study a value of $\beta=0.1$ is taken, the atmosphere is clear, which indicates a cloudiness-free sky, of blue color, which has place only in determined occasions. For a $\beta=0.2$, the atmosphere presents clear sky conditions with slight cloudiness, a characteristic that is more common and some authors identify them as a light blue sky, with some haze. For a $\beta=0.3$ the atmosphere presents a degree of turbidity that indicates greater cloudiness, under these conditions it has a pale blue color, with more lime. For a $\beta=0.4$, the atmosphere appears cloudy; in this case, the sky presents a "milky" color characteristic of extreme haze.

Regarding the diffuse radiation, the model considers three solar components, the $I_{dr}$ due to the existence of air molecules, $I_{da}$ due to the existence of dust particles, and $I_{dm}$ which is by multiple reflection between the soil and the atmosphere [6].
The diffuse radiation due to the existence of air molecules is described by the Eq. (3).

\[ l_{dr} = \left[ \frac{0.79 \cdot C_r \cdot \tau_0 \cdot \tau_g \cdot \tau_w \cdot \tau_{aa}}{2} \right] \cdot \left[ \frac{1 - \tau_r}{1 - m_a + m_a^{0.02}} \right] \cdot \text{sen}(A) \ (\text{W/m}^2) \]  

where \( \tau_{aa} \) corresponds the transmittance due to the absorption of aerosols which is a function of the air mass \((ma) \) and the transmittance due to aerosols \( \tau_a \) used for the calculation of direct radiation.

In this model, the transmittance value by scattering \((\tau_r)\) evaluates the change of direction that the solar radiation experiences due to the air molecules presence and it’s determined from the Eq. (4).

\[ \tau_r = e^{-0.0903 \cdot m_a^{0.84} (1+m_a - m_a^{1.01})} \]  

For their calculation, it is necessary to determine the optical mass of the air \((m_a) \) which is corrected by pressure as shown by the Eq. (5).

\[ m_a = \frac{P_T \cdot m_{rel.}}{1,013,25} \]  

Where \( P_T \) es the total pressure of the air in Pa and it is determined in function of the altitude \((z)\) with the Eq. (6) [6].

\[ P_T = 101,325 \cdot e^{-0.0001184 \cdot z} \]
To calculate the air mass value, it is required to evaluate first the relative air mass value ($m_{rel}$). This is determined by Eq. (7).

$$m_{rel} = \frac{1}{\cos U + 0.15 \cdot [93.885 \cdot U]^{-1.253}}$$

(7)

Diffuse radiation due to the presence of aerosol sprays, represented by the Eq. (8), is calculated from the C Model of Iqbal [7], which is function of the energy percentage that approaches to the Earth surface due to the aerosol spray dispersion ($F_c$). In this case, its value can be estimated from the parametrization realized by Mac, whose calculation is function of the atmospheric mass ($m_a$) [8].

$$I_{da} = 0.79 \cdot C_r \cdot \tau_0 \cdot \tau_g \cdot \tau_w \cdot \tau_{aa} \cdot F_c \cdot \left[ \frac{1 - \tau_{as}}{1 - m_a + m_a^{1.02}} \right] \cdot \text{sen}(A) \text{ (W/m2)}$$

(8)

In this equation the transmittance is used ($\tau_{as}$) which is due to the aerosol spray diffusion which is function of ($\tau_a$) and ($\tau_{aa}$).

The calculation of the diffuse radiation by multiple reflection, represented by the Eq. (9), requires having the surface reflection coefficients ($\rho_0$), this value is generally tabulated. In the same way, it is required to evaluate the atmospheric albedo; that is, the multiple reflection between the soil and the sky ($\rho' a$) which is function of $F_c$ and the transmittance due in exclusiveness to diffusion by aerosol sprays [9].

$$I_{dm} = [I_{DH} \cdot \text{sen}(A) + I_d + I_{da} \cdot \left( \frac{\rho_g \cdot \rho_a}{1 - \rho_g \cdot \rho_a} \right)] \text{ (W/m2)}$$

(9)

As it was mentioned earlier, this model indicates that the solar irradiation is equivalent to the sum of the direct and diffuse irradiation as presented in the Eq. (10).

$$I_{TH} = I_{DH} + I_{dH}$$

(10)

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Marley Vanegas Chamorro: Conceptualization, Methodology, Validation, Writing - original draft. Edwin Espinel Blanco: Data curation, Funding acquisition. Jhan Piero Rojas: Formal analysis, Resources.

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Supplementary Materials

Supplementary material associated with this article can be found, in the online version at doi: 10.1016/j.dib.2020.106397.
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