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Clarity Index in the city of Manaus in Global Atmospheric Radiation Measurement function by Meteorological Observation Station in the Amazon ranking

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ABSTRACT
The data for this study are based on actual observations of global irradiation of the database provided by the National Institute of Meteorology-INMET during the period 2013 to 2015, by registered Meteorological Observation Automatic Station A101 located in the city of Manaus in Amazonas state. These data were used to determine the Clarity Index in order to classify the types of predominant sky in the Amazon municipality in the period studied, for planning purposes of photovoltaic power generation. The research also contributes to the algorithm in MATLAB to determine the distance Earth-Sun, Solar Irradiation Extraterrestrial and the Clarity Index. The results come from the analysis were obtained through Matlab and Excel software that enabled the realization of the sky classification based on the results of the Clarity Index.
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Keywords: Earth-Sun distance, irradiation, Irradiation Solar Alien, Global Irradiation, Clarity Index.

Índice de Claridade no Município de Manaus em função da Radiação Atmosférica Global Medida pela Estação de Observação Meteorológica no Estado do Amazonas

RESUMO
Os dados para esse estudo são baseados em observações reais de irradiação global do banco de dados fornecido pelo Instituto Nacional de Meteorologia-INMET durante o período de 2013 a 2015, através de registrados da Estação Meteorológica de Observação Automática A101 localizada no Município de Manaus no Estado do Amazonas. Dados estes que foram utilizados para a determinação do Índice de Claridade com o objetivo de classificar os tipos de céu predominante no Município do Amazonas no período estudado, para fins de planejamento de geração de energia fotovoltaica. A pesquisa ainda, contribui com o algoritmo em MATLAB para a determinação da distância Terra-Sol, Irradiação Solar Extraterrestre e o índice de Claridade. Os resultados oriundos da análise foram obtidos através dos softwares Matlab e Excel que permitiram a concretização da classificação do céu com base no resultado do Índice de Claridade.
Palavras chaves: Distancia Terra-Sol, Irradiação, Irradiação solar extraterrestre, Irradiação Global, Índice de Claridade.

I. INTRODUCTION

The land is considered an opaque surface,, does not allow any light to pass through. When radiation hits an opaque surface, part of it is reflected and absorbed another. The albedo of a surface is the ratio of energy reflected on the incident, expressed radiation fraction reflected by the surface [2].

The atmosphere consists of several gases, such as nitrogen, oxygen, hydrogen, ozone, carbon dioxide, methane, and others which are mixed and in contact with tiny particles, called aerosols, forming a complex mixture, most of which, about 99% contained at a height of 30 km on the earth 's surface [5].

When a radiant energy flow propagates in the atmosphere, it interacts with components and undergoes attenuation, which results from two distinct phenomena called absorption and scattering. Absorption is the process by which the radiant energy is transformed into another type of energy, typically heat. While scattering is the process in which the radiant energy flow is diverted from its abnormal trajectory without loss of energy. The components are classified as direct solar radiation, diffuse solar radiation and global solar irradiation [2] and [8].

The set of all frequencies of electromagnetic waves carries energy that can be captured in the form of heat or through the generation of electric energy. Before reaching the atmosphere, solar radiation is composed of approximately 53% of invisible radiation, with a small portion of infrared light and a large portion of ultraviolet light and 47% of visible light that is captured by the human eye and also used by plants To perform photosynthesis [19].

Direct sunlight is the solar radiation that passes through the Earth 's atmosphere without undergoing any change in its original direction, that is, come directly from the sun straight and focus on the horizontal plane with a slope that depends on the zenith angle of the sun. This type of radiation can be measured by an instrument called pireliômetro, comprising a solar radiation sensor installed inside a tube with a narrow light opening, which is achieved only by the direct light emitted by the sun [18][15] and [8].

The horizontal diffuse solar radiation is the solar radiation that passes through the atmosphere coming indirectly to the plane due to the sun's rays undergo diffraction, or are scattered by the gases composing the atmosphere, and also pass through the light reflection process in the dust, the clouds and other objects. The radiation from the reflection of the sun's rays from their neighborhood, called albedo radiation. Among which are exemplified: the solar radiation received by vegetation, construction, soil, asphalt and other [18][15]and [8].

Irradiation global horizontal is the sum of the direct radiation and diffuse radiation, such radiation can be measured by an instrument called a pyranometer, consisting of a radome glasses that receives light in all directions and focuses on a solar radiation sensor installed inside [18][15] and [8].

Air pollution potentiates the effects of absorption and scattering of solar radiation. Due to these factors, the maximum irradiance that reaches the Earth's surface is around 1,000 W / m². While in outer space, the average distance between the Sun and Earth, the irradiance is about 1353 W / m $^{2.}$ To evaluate the efficiency of photovoltaic panels is used as a standard irradiance of 1000 W / m ^{2} [12].

Solar radiation provides annually to the Earth's atmosphere 1.5 x 1018 kWh of energy sustaining life on earth, being responsible for the dynamics of the atmosphere and the main climatic feature of planet Earth. The knowledge of the incident solar radiation on Earth plays a key role in many human activities, such as, agriculture, architecture and energy planning. The amount of radiation that reaches the horizontal plane depends on the geographic location of the weather and seasons [9].

Mathematical models are used to determine the solar radiation models such as the Angstrom-Prescott equation are used to estimate the global solar radiation. The orders of the day of the year, the solar declination, the time of the angle of the sun, photoperiod, the Earth-Sun distance are important variables and directly influence in determining the Clarity Index to classify the type of sky at a given location [21].

The clearness index is a basic component for determining through parameterization the conditions of the sky in a certain place, which allows evaluating the transition conditions between a completely overcast sky to a clear sky with low turbidity. Study on cloud cover allows to evaluate the weather - related condition it is in the sky at a given time and place, conditions which are assessed through the clearness index that indicates the presence or absence of clouds in the sky [7].

A methodology to determine the classification of the type of sky due to the Clarity Index, determining a parameter to classify the sky overcast, when the value of Clarity Index presents from 0 to 0.3, partly cloudy when value of Clarity Index present is between 0.3 and 0.65, and clear when the Clarity Index is presented between 0.65 and 1.0, has been developed [15].

The parameters used by [15] will also be used in this research to classify the predominant type of sky in the city of Manaus, state of Amazonas.

Knowing the types of clouds over particular location is important for the planning of projects for the production of photovoltaic energy, as the clouds reduce the amount of solar energy absorbed in the atmosphere.

1. BIBLIOGRAPHICAL REVIEW

2.1 Geographical coordinates of the city of Manaus

The geographical coordinates are imaginary lines that cross the Earth in horizontal and vertical directions, which serve to locate any point on the surface of planet Earth, through the intersection of a meridian with a parallel.

There are two types of geographical coordinates Latitudes and Longitudes:

Geographic latitude is the angle measured along the meridian passing through the place formed between the terrestrial Ecuador and the point considered. All terrestrial Equator points have Latitude geographic equal to 0. Points situated to the north of Ecuador have Latitudes higher ranging from 0 ° to 90 °. Similarly vary Latitudes south of the terrestrial Ecuador that have the range of 0 to 90 °. To differentiate the values attributed to positive sign for the North Latitudes and negative for South Latitudes. Latitude is an important element to explain the thermal differences, ie the temperature differences in the Earth 's surface. The temperatures decrease from Ecuador to the poles Thus, when the latitude lower, the higher the temperature [16].

Geographic longitude is the angle measured along the equator formed between the meridian passing through the place and the meridian passing through the town of Greenwich, England. The length is measured from 0to 180 the, to the east or west of Greenwich. By convention, also assign signals to the longitudes: negative to positive West and to the East. Knowing the values of Latitude and Longitude, determine the geographical coordinates of the same [3],[16][17].

Through software *on* geolocation *line* you can identify the geographical coordinates of a given location. In the case of Manaus city municipality, the Latitude is equal to 03º07'08,499"ao South in decimal coordinates equal to -3.1190275 and longitude 60º01'18,2333 " the West in decimal coordinates equivalent to -60.0217314 (GEOLOCALIZADOR, 2016) on the site (http://pt.mygeoposition.com) access 5 August 2016; [16] on the site (http://www.sunearthtools.com) access 5 August 2016.

Figure 1 illustrates the geographical location of the city of Manaus through satellite data with geographical coordinates already mentioned.

Figure 1: Location satellite map of the city of Manaus.
Fonte: http://24timezones.com/mapa_pt/manaus.php, acesso 19/09/2016.

2.2 Distance Earth-Sun

For radiant energy studies on Earth, the sun can be considered a point source of energy that radiates equally in all directions. So if the light intensity is at a given time equal to I, the total energy emitted is equal to. At that moment, the Earth is located in a hypothetical sphere of radius equal to the Earth-Sun distance (D) *area,* which will be intercepting the energy emitted (4 πI). Thus the solar radiation flux, ie the solar radiation on the spherical surface is given by the ratio 1[11]:

$$\frac{4\pi I}{4\pi D^2} = \frac{I}{D^2} \qquad (1)$$

This relationship defines the Law of Distance Square Inverso, where the energy received on a surface is inversely proportional to the square of the distance between the emission source and the receiving surface.

The ratio of 2 is given to determine the distance Earth-Sun:

$$E = (\frac{d}{D})^2 = 1 + 0.033\ x\ \cos(\frac{2\,\pi NDA}{365}) \qquad (2)$$

At where:
And it is the Earth-Sun distance.
d is the average Earth-Sun distance
D is the Earth-Sun distance on a specific day.
NDA is the order of the days of the year from 1 January.

Figure 2 graphically displays the result of the Earth-Sun distance throughout the year, it is observed that the Earth-Sun distance is greater in the first three months of the year in January, February and March and the last three months of the year October, November and December. While smaller distances Earth-Sun are observed in June and July.

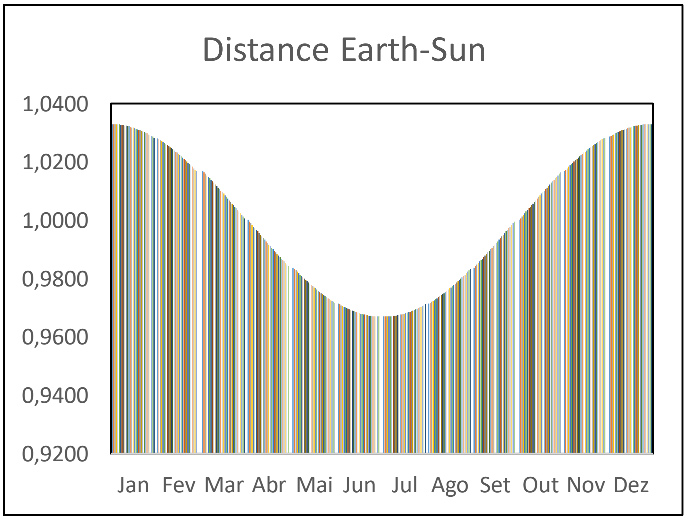


Figure 2: Earth-Sun distance according to Months of the year
Source: Authors, (2016).

2.3 Declination Solar

Solar declination is the angular position s of the rays of sunlight at noon on the local meridian, in relation to the plane of the equator obtained by the relationship 3, Cooper according to equation [14]:

$$\delta = 23.45\ x\ sen\left(\frac{2\pi}{365}(NDA + 284)\right) \qquad (3)$$

At where:

NDA is the matrix that represents the order of the days of the year from 1 January.
δ It is the solar declination in the days of the year.

The planet earth with a slope of 23.5º and rotating on a throne of its own axis throughout the year, presents a declination angle that changes with the passing of the year (MCTI, 1999).

It is observed in Figure 3 that the solar declination during the year presents with increasing results in the month of January to break the 21 or 22 June. On January the result of solar declination is -23.01, nullifying in the March 22 and reaching its maximum on 21 and 22 June with 23 record, 45. From the period of June 23 to December solar declination shows decreasing negative results coming very close to be canceled on days 21 or 22, solar declination reaches its lowest level on 20 or 21 December to -23 record, 45 .

The moment the solar declination presents with respective angles 23,45º and -23,45º means of earth's rotation axis is in the plane perpendicular to the ellipse plane passing through the center of the earth, a phenomenon known as solstice means Sun stopped.

On 21 or 22 June, the Earth prepares to reach its point of greatest declination, the northern hemisphere receives more sunlight intensity compared to the South. Thus, begins in the Northern Hemisphere summer and in the hemisphere South winter. Therefore, we have the summer solstice. On December 21, the earth prepares to reach its point of least declination, the Northern Hemisphere receives less sunlight than the Southern Hemisphere, so starting in the northern hemisphere winter and in the southern hemisphere summer. So, we have the Winter Solstice.

It is observed also in Figure 3 that in the days March 22 and 20 or 21 September-earth inclination 0 °, allowing both hemispheres receive the same amount of sunlight, therefore the days have the same length as the nights a phenomenon known as the Equinoxes. On March 22 begins in the northern hemisphere and spring in the southern hemisphere autumn. On 20 or 21 September starts in the Northern Hemisphere and autumn in the southern hemisphere spring.

$$Hn = cos^{-1}(-tg\phi . tg\delta) \quad (4)$$

At where:

is the Sun hour angle at sunrise (-) and Sunset (+).
□ is the local Latitude in degrees.
□ is the solar declination in degrees.

Figure 4 shows graphically the hour angle in the East and the West. It is observed that the Sun real time angle have varying 88 to 91, being higher in the months of January and December. During the year the Sun hour angle True decreases, reaching its minimum on June 21 presenting angle of 88 hours, 6456º. While the maximum amount of sun hour angle is observed on December 21 with a value of 91, 3544º.

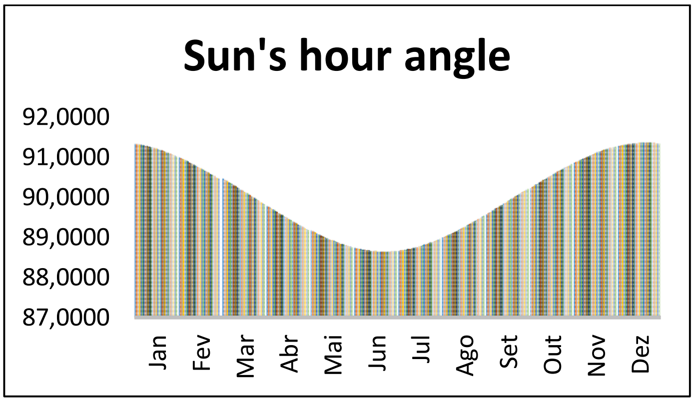


Figure 4: True Sun's Hour Angle throughout the year in the Municipality of Manaus.
Source: Authors, (2016).

Photoperiod is the time that the sun remains above the horizon, covering the period from sunrise to sunset. After determining Hn is the photoperiod, which is defined as the amount of sunlight hours at a particular location according to the ratio of [20] e [6].

$$N = \frac{2.Hn}{15} \quad (5)$$

At where:
It is in hours photoperiod
Hn is the hour angle of the sun.
Figure 5 graphically displays photoperiod in the city of Manaus, where the sun above the horizon period corresponds on average 12 hours in the beginning of the year in January,

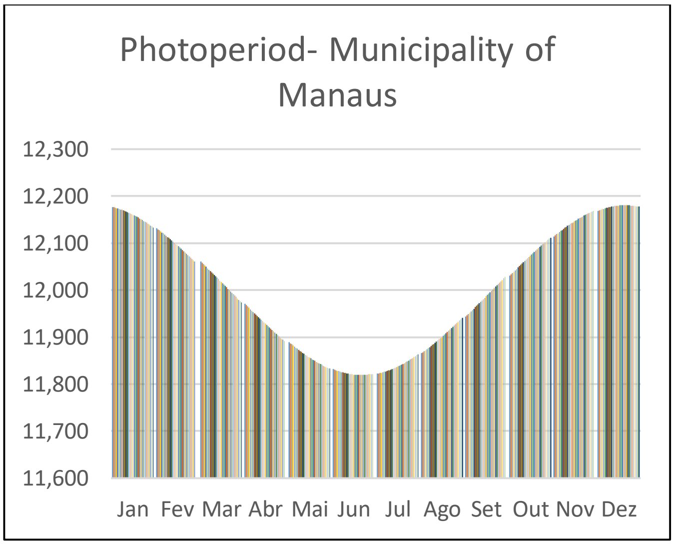


Figure 5: photoperiod according to the months of the year
Source: Author, (2016).

February and until the 22th of March.The same applies to the period from 21 September to 31 December. The photoperiod lasting 11 hours on average occurs in the period from 23 March to 20 September, where the minimum photoperiod of hours is observed on 20, 21 and 22 June with the amount of approximately 11,819h.

2.4 Irradiation extraterrestrial Solar

The average variation of extraterrestrial solar irradiance, provides us the value of the solar constant (K), which is the solar irradiance on a flat surface perpendicular to the sun without the mitigating effects of the atmosphere and at a distance average Earth-Sun 1,367 W / m ^{2} [1].

The extraterrestrial solar irradiance is given by the ratio 6 [11].

$$Qo = 37{,}6 \; x \; (\frac{d}{D})^2 \; x \; [\left(\frac{\pi}{180}\right) \; x \; Hn \; x \; sen\theta \; x \; sen\delta + cos\theta \; x \; cos\delta \; x \; \sin(Hn) \quad (6)$$

At where:

Qo is the extraterrestrial solar radiation in MJ / m $^{-2}$ day $^{-1.}$
$(\frac{d}{D})^2$ is the Earth-Sun distance.
Hn is the hour angle of the Sun.
θ It is the local latitude
δ It is the solar declination

Figure 6: Irradiation Solar Extraterrestrial according to the months of the year.
Source: Authors, (2016).

2.5 Clarity Index

The clearness index is a basic component for determining through parameterization the conditions of the sky in a certain place, which allows evaluating the transition conditions between a completely overcast sky to a clear sky with low turbidity. Study on cloud cover allows to evaluate the weather-related condition it is in the sky at a given time and place, conditions which are evaluated by Clarity Index that indicates the presence or absence of clouds in, defined by the ratio 7 per [7].

$$Kt = \frac{Qg}{Qo} \quad (7)$$

According [15] type of heaven will be classified as cloudy presents value of Clarity Index from 0 to 0.3, partly cloudy present Clarity Index value between 0.3 and 0.65, and clear sky appears Clarity Index between 0.65 and 1.0.

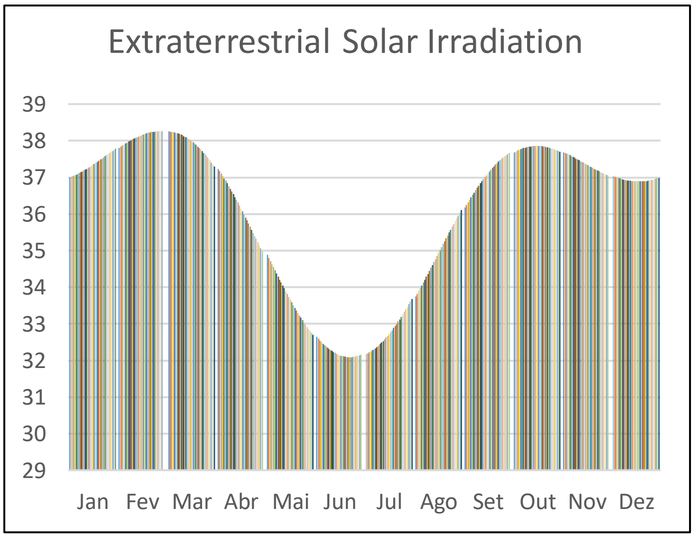
3 MATERIALS AND METHODS

In order to determine the clarity index an algorithm was elaborated using MATLAB software, where equations (1), (2), (3), (4), (5), (6) and (7) were used. The elaborated algorithm allows us to know the solar declination throughout the year and also specifically on a desired day, as for example DEC (21,3). The algorithm also allows us to know the hour angle of the sunrise in the city of Manaus, the photoperiod, the distance Earth Sun in each day of the year, the estimation of extraterrestrial solar irradiance in MJ / m2dia and determines the global solar irradiation estimate in Every day of the year

In this research the global solar irradiation was provided by the National Institute of Meteorology INMET through the A101 Observation Station restricted to the years 2013 to 2015, allowing us the real knowledge of the index of clarity in the city of Manaus.

Algorithm to determine the clarity index

```
% Local Latitude, this study Manaus.
LAT = 3.1190275;
% Declination in certain day DEC
% Matrix days over the months
A = [1:31; 0 32:60 0; 60:90; 91: 0 120; 121: 151; 152: 0 181; 182: 212; 213: 243; 244: 0 273; 274: 304; 305: 0 334; 335: 365];
% Matrix NDA orders days of the year and A 'is the transposed matrix of the matrix A
NDA = A ';
 % DEC solar declination
DEC = 23:45 * (sin ((2 * PI / 365) * (284 + NDA)))
  % To determine the value of the solar declination on a specific day in the case
  % Cited here is determined by the solar declination for October 1.
DEC (21,3);
  % Schedule Angulo Sunrise
```




```
cosHn = -tand (LAT) * tand (DEC.);
Hn = acosd (cosHn);
% photoperiod
Terming% photoperiod N
N = (2 * Hn) / 15;
% Calculatlabtion of the distance Earth-Sun
E = 1 + (0.033 * cos (2 * pi * NDA / 365));
  % Distance calculation Earth-Sun on October 1
E (1.10);
% Calculation Estimate of extraterrestrial solar radiation [MJ / m²dia]
Qo= 37.6 * E. * ((* Hn (pi / 180). * Sind (LAT). * Sind (DEC)) + (cosd (LAT). * Cosd (DEC). * Sind (Hn)))
% Estimated global daily solar radiation on the surface [MJ / m²dia]
% Data provided by
% Index Clarity
Kt = Qg./Qo
```

Using the global irradiation data provided by Automatic Weather Station Observation A101 and relations 6, it was determined the predominant Lightness index in the city of Manaus. It is observed that in 2013 at 2015 the predominant type of sky is partly cloudy.

4 RESULTS AND DISCUSSIONS

Using the algorithm and the measurements of Global Irradiation it was possible to determine the results represented by those represented in figures 7 to 17 below.

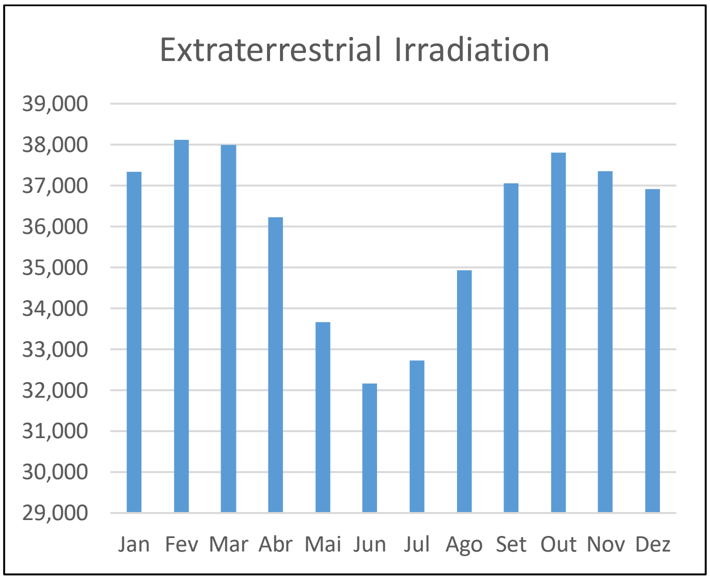


Figure 7: Estimation of extraterrestrial solar irradiation.
Source: Authors, (2016).

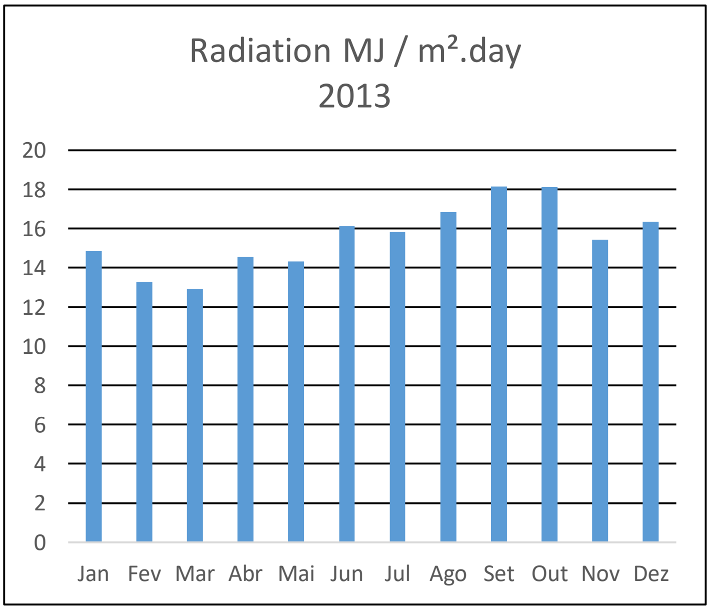


Figure 8: Global Irradiation in MJ in the municipality of Manaus in 2013.Source: (Adapted) INMET, (2016).

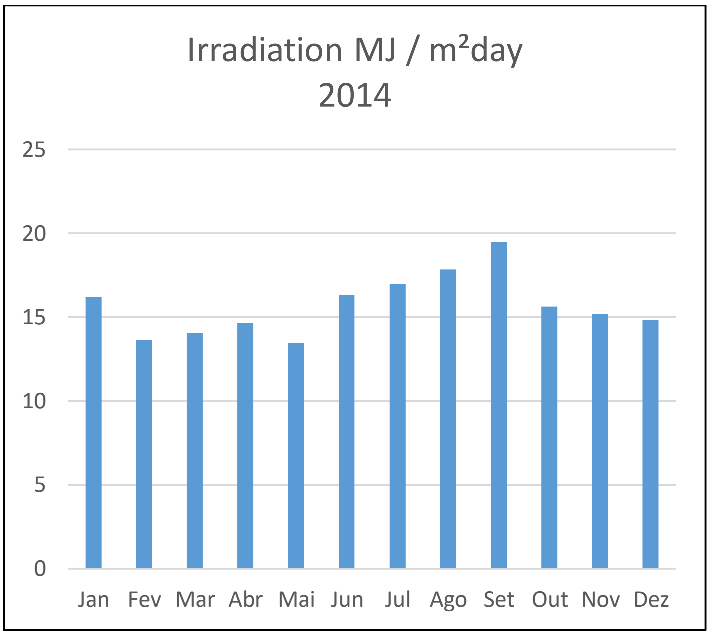


Figure 9: Global Irradiation in MJ in the municipality of Manaus in 2014.
Source: (Adapted) INMET, (2016).

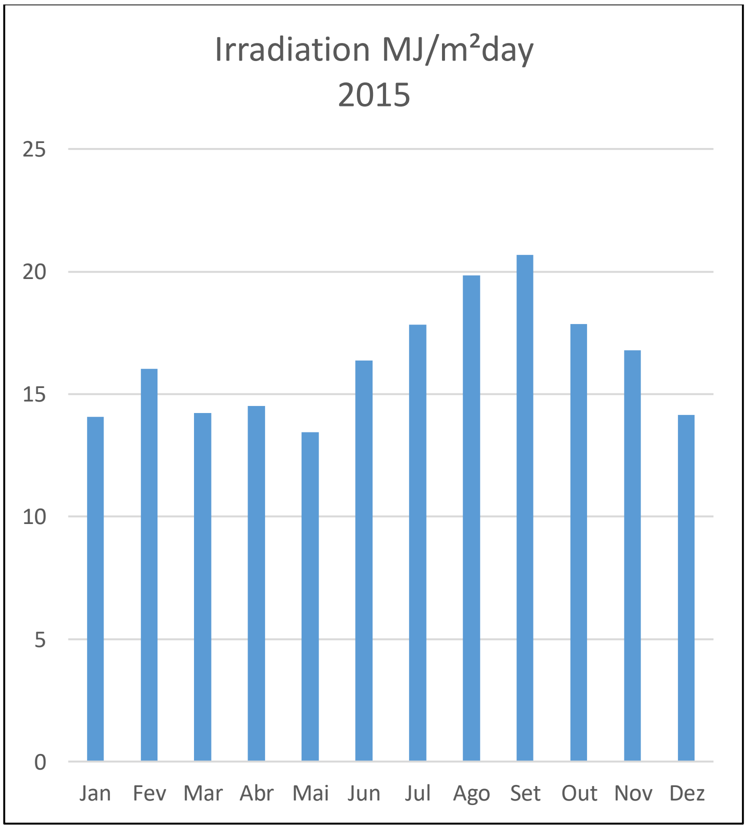


Figure 10: Global Irradiation in MJ in the municipality of Manaus in 2015.
Source: (Adapted) INMET, (2016).

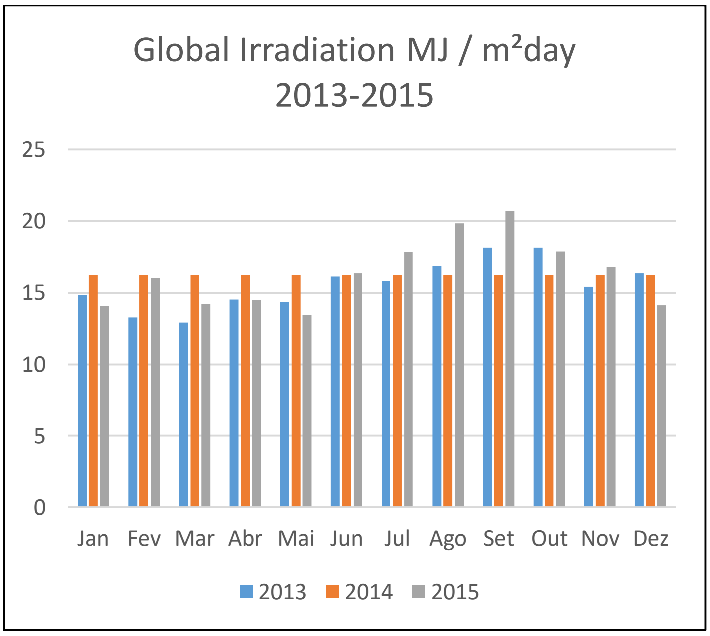


Figure 10: Global Irradiation in MJ in the municipality of Manaus in 2013-2015.
Source: (Adapted) INMET, (2016).

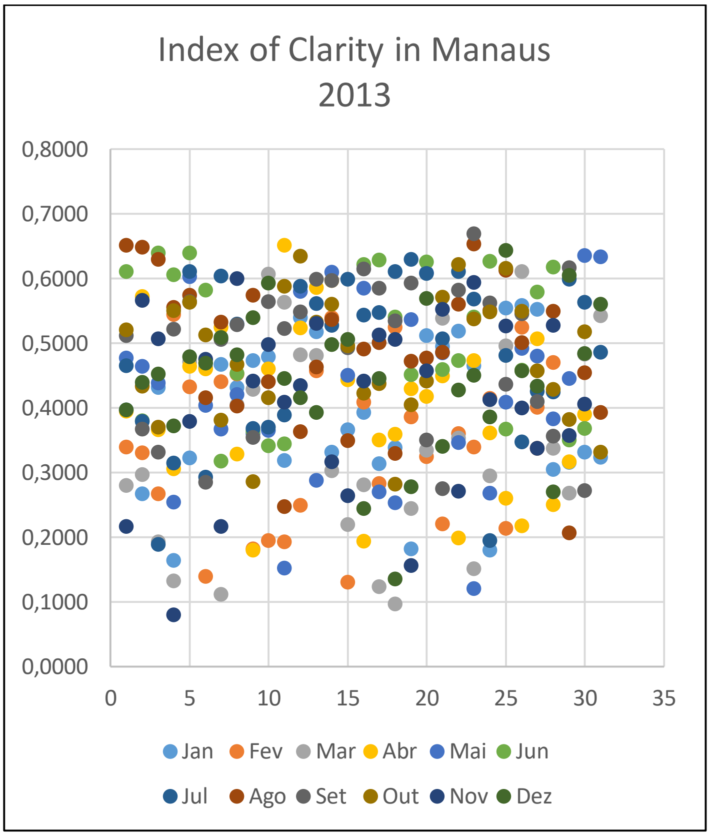


Figure 11: Clarity Index in Manaus in the year 2013.
Source: Authors, (2016).

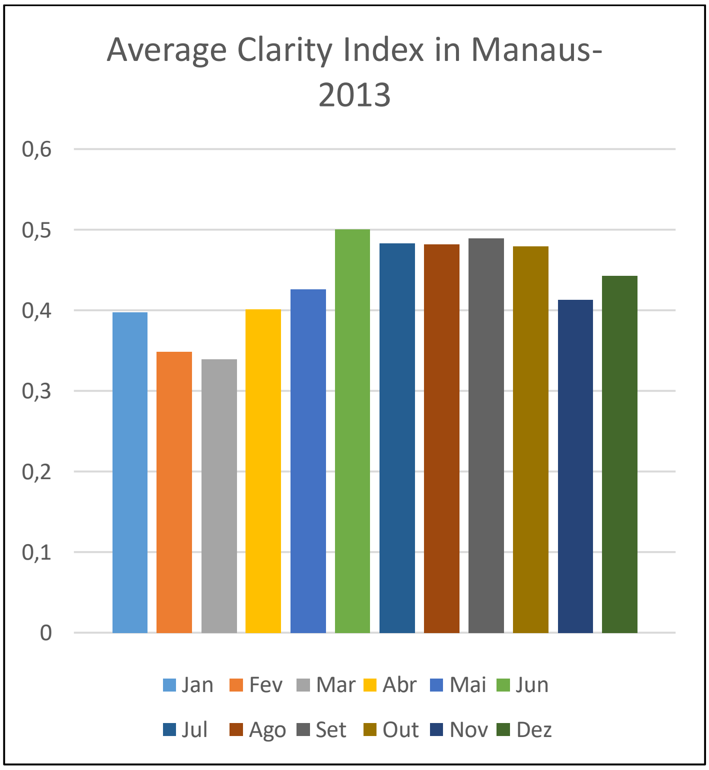


Figure 12: Clarity Index in Manaus in the year 2013.
Source: Authors, (2016).

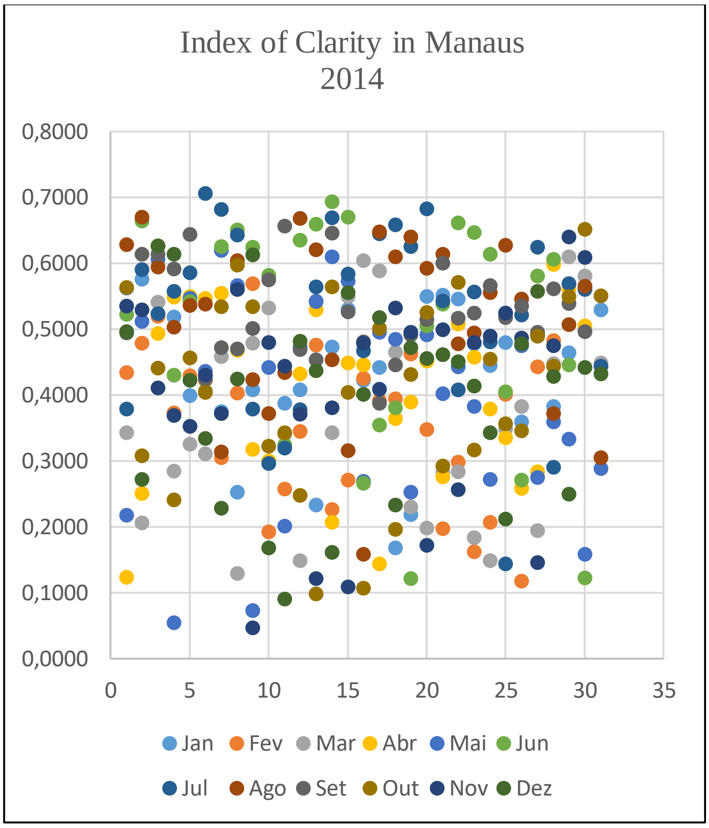


Figure 13: Clarity Index in Manaus in the year 2014.
Source: Authors, (2016).

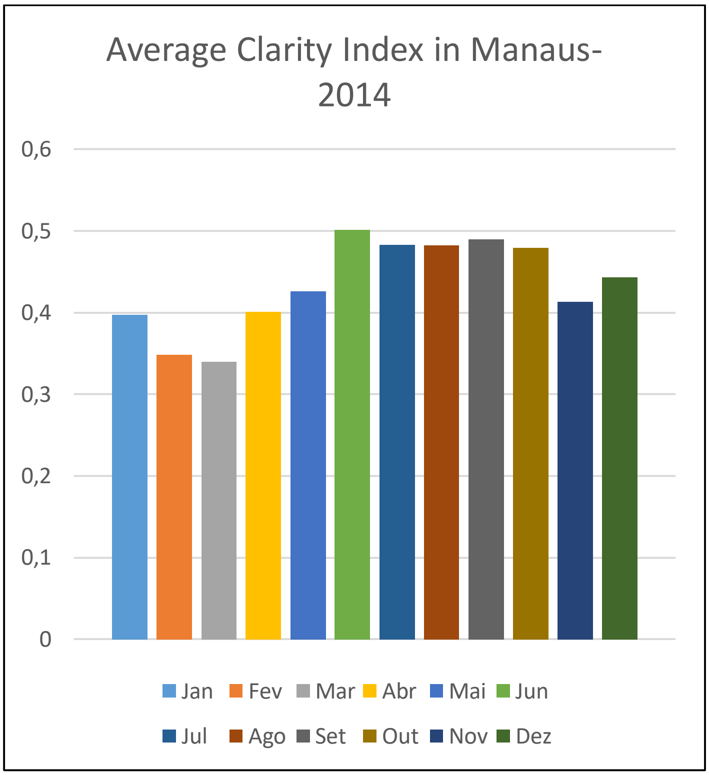


Figure 14: Clarity Index in Manaus in the year 2013.
Source: Authors, (2016).

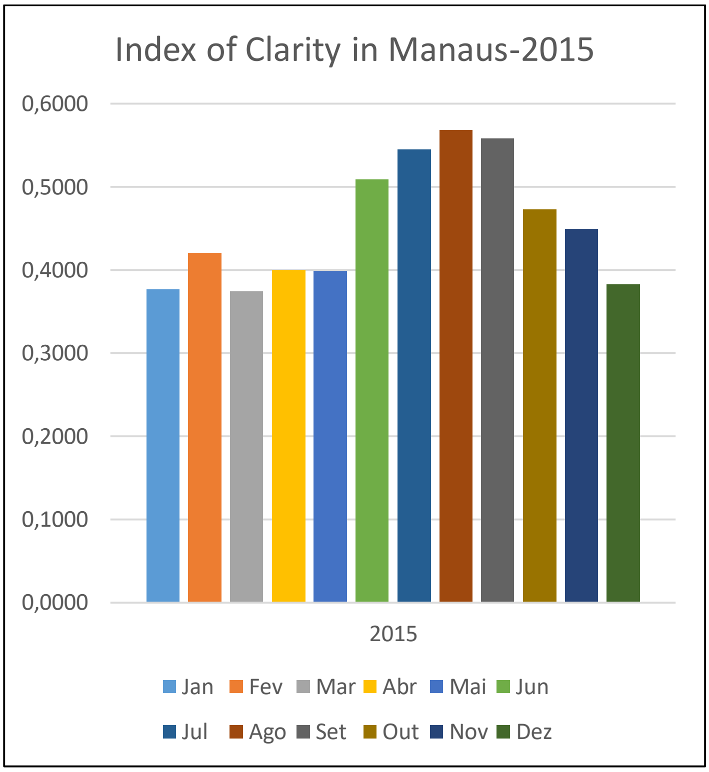


Figure 16: Clarity Index in Manaus in the year 2013.
Source: Authors, (2016).

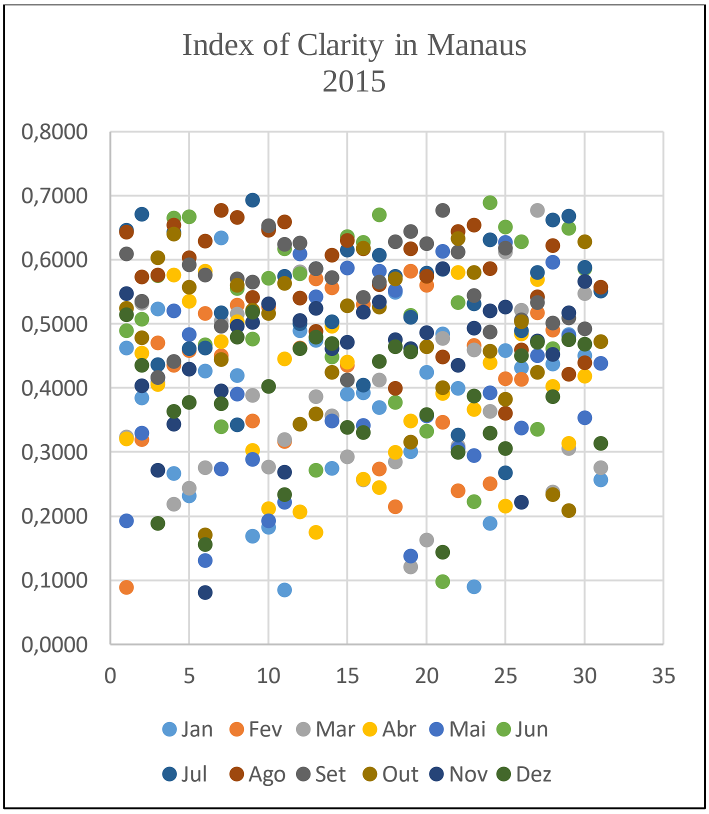


Figure 15: Clarity Index in Manaus in the year 2013.
Source: Authors, (2016).

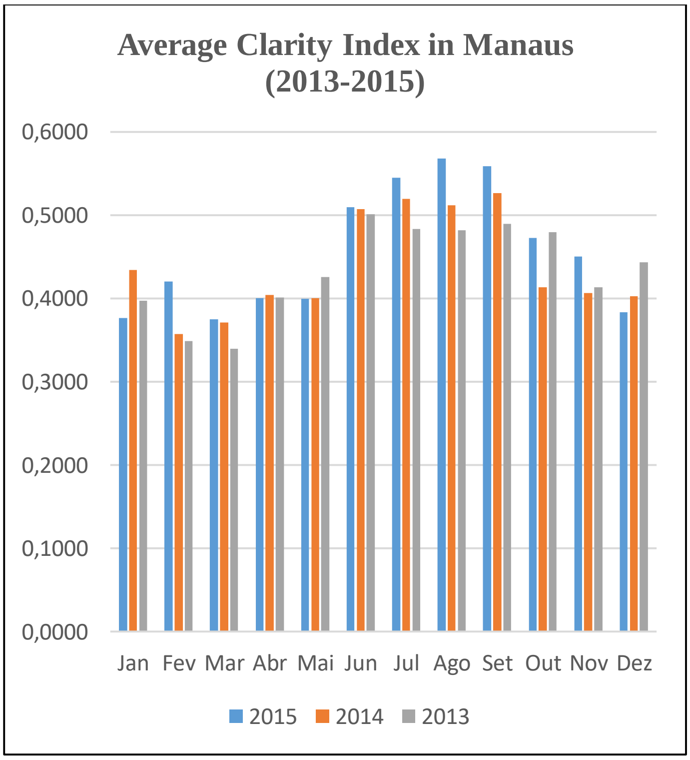


Figure 17: Clarity Index in Manaus in the years 2013-2015.
Source: Authors, (2016).

5 CONCLUSION

The objective of this article was to develop an algorithm that allowed calculating the estimation of extraterrestrial solar irradiation and using the global irradiation data provided by the A101 Automatic Weather Station located in the city of Manaus and using the relations 6, it was possible to evaluate the type of sky Predominant in the Municipality of Manaus through the study of Clarity index.

The study of the Sky Clarity Index is important because it is directly correlated with the global radiation that is the main source for the production of photovoltaic energy. Knowing the types of sky predominant in a particular place is knowing the types of clouds and consequently the types of shadowing caused by the incidences of these clouds and the interference in the production of photovoltaic energy generation.

Therefore, when designing a photovoltaic system installation, it is essential to know the predominance of clouds to estimate the potentiality of energy that the photovoltaic system can produce at the installation site of the photovoltaic system.

The result of the research shows that the Municipality of Manaus presents classification of cloudy sky in some days of the year, partly cloudy most of the days of the year and cleaned in some days of the year. However, the predominant classification for the sky type in the Municipality of Manaus, are in the range of 0.3 to 0.6 that classifies the sky type in Partly Cloudy.

The study of the clarity index also shows that the months of the year with the best indexes of clarity are the months of June, July, August and September.

Comparing the data presented in the graph of figure 13 that analyzed the results of the clarity indices2013 to 2015 it was observed that the highest indices of clarity were verified in the year 2015.

6 ACKNOWLEDGMENTS

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