Solar radiation in Salvador and its impacts on health

A radiação solar em Salvador e seus impactos na saúde

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1 INTRODUCTION

The recent increase in research related to solar power generation, in the search for better efficiencies and more suitable cities for the production of photovoltaic energy, also demonstrates the need for caution about the effects of solar radiation (such as ultraviolet radiation) for those venturing into this growing branch of solar energy, since many workers are exposed during the installation and maintenance of solar panels.

Using the solar radiation for the period between January 1st, 2021 and December 31st, 2021 in the city of Salvador, we sought to make a comparison of the effects of the months with the greatest capacity for solar energy production with the data caused by solar radiation. Listing the pros and cons of the technology and health care.

2 OBJECTIVE

Create a summary about the effects caused by the types of ultraviolet radiation relating it to solar radiation for Salvador.

3 METHODOLOGY

The work is based on a literature review with real data in order to create a summary about the effects caused by the types of ultraviolet radiation relating it to solar radiation. Data obtained from the city of Salvador in the period January 01, 2021 to December 31, 2021 through the INMET website were used to demonstrate the periods with higher solar radiation and higher temperatures.

4 DEVELOPMENT

The effects of solar radiation on the skin

With several benefits for living beings, such as the photosynthesis phenomenon in vegetables, the synthesis process of vitamin K and vitamin D, the sun's rays are necessary for life on earth (KULLAVANIJAYA; LIM, 2005; SANTOS, 2007; SILVA, 2008). However, when in excess, solar

radiation causes several problems. Mainly due to solar radiation with several wavelengths, being the ultraviolet radiation (UV) the most harmful to humans (FLOR; DAVOLOS; CORREA, 2007; MATHEUS; KUREBAYASHI, 2002).

Among the effects caused by UV radiation, we mention the production of free radicals and reactive oxygen species in the skin, responsible for dermatological reactions with irreversible consequences. This causes DNA lesions, such as photoaging through alterations in the elastic fibers, and the disarrangement and destruction of collagen fibers, as well as the decrease in the number of Langerhans cells, affecting the immune response of the skin (WEBBER; RIBEIRO; VELÁSQUEZ, 2005; OKUNO; VILELA, 2005; SILVA, 2007).

If the exposure is not diminished, it favors the appearance of the most worrying effect when it comes to health, the appearance of skin cancer, can be divided into melanoma and non-melanoma.

It can appear anywhere in the body in the form of spots, speckles or signs, melanoma skin cancer is the most serious type, due to its high possibility of causing metastasis (cancer dissemination to other organs) (MINISTRY OF HEALTH, 2021). Estimated new cases in Brazil: 8,450, 4,200 men and 4,250 women (2020-INCA). Number of deaths in Brazil: 1,978, with 1,159 men and 819 women (2019-Cancer Mortality Atlas- SIM).

Non-melanoma skin cancer, on the other hand, is the most frequent in Brazil and has the lowest mortality rate, sometimes causing mutilations if not treated properly, and has a high chance of being cured, as long as it is detected and treated early.

Estimated new cases in Brazil: 176,930, being 83,770 men and 93,160 women (2020 - INCA) Number of deaths in Brazil: 2,616, being 1,488 men and 1,128 women (2019 - Atlas of Cancer Mortality - SIM) (MINISTRY OF HEALTH, 2021).

Solar radiation

Sunlight, also known as solar radiation, refers to the light received on Earth that originated from the Sun. This light represents a portion of the electromagnetic spectrum that includes infrared light, visible light, and ultraviolet light. About half of the radiation is in the visible portion of the solar spectrum, with most of the rest in the near infrared section with a comparatively small amount in the ultraviolet spectrum (BABATUNDE *et al.,* 2022.). Sunlight striking the Earth's surface has been filtered through the atmosphere, with some of the ultraviolet radiation being absorbed. Radiation that is not absorbed by the atmosphere can produce a tan or sunburn.

The average amount of energy from the sun absorbed by the earth is about 70% of the incident energy and this amount of energy can be used as solar energy in solar thermal power plants or photovoltaic cells.

The total solar irradiance is the maximum power delivered to the earth's surface, assuming that the path of incident light is perpendicular to that surface (GUPTA *et al.*, 2022).

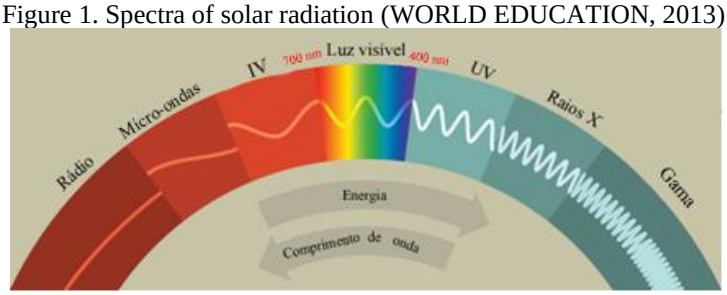
A solar panel, or solar module, is a component of a photovoltaic system. They are constructed from a series of photovoltaic cells arranged in a panel. They come in a variety of rectangular shapes and are installed in combination to generate electricity (ANAND B. *et al.*, 2021).

Solar radiation helps in the formation of vitamin D3, which fixes calcium in bones, fighting rickets and osteoporosis. In excess it causes severe aggression to human skin, mainly by ultraviolet radiation that makes up the solar spectrum (CETESB, 2020).

5 ULTRAVIOLET RADIATION

Sunlight is composed of three radiations: infrared, visible light and ultraviolet. The region of the electromagnetic spectrum emitted by the Sun that comprises the ultraviolet radiation is between the wavelengths of 200 nm and 400 nm, subdivided into three bands, UVA, UVB and UVC, taking into account its propagation characteristics and physiological effects (MATHEUS; KUREBAYASHI, 2002; GUARATINI, 2008). The spectrum of solar radiation can be demonstrated in Figure 1.

Figure 1. Spectra of solar radiation (WORLD EDUCATION, 2013).



The most damaging and energetic is UVC, and it does not reach the earth because it is filtered by the ozone layer. Showing an important function of the ozone layer and how dangerous it will be if it is extinguished. UVC in contact with the earth would have the ability to kill single-celled organisms and harm the cornea of the eyes (WORLD EDUCATION, 2013).

Hitting the earth in small proportions, UVB is the second highest energy of ultraviolet radiation, causing redness and some types of cancer. So UVA ends up being the most dangerous, when comparing conditions such as exposure, because it penetrates more into the skin and is present all day long.

Ultraviolet radiation acts in the formation of free radicals inside cells, which can cause damage such as premature aging. Research shows that changes in skin immune system function can occur after a single burn, and skin cancer has been associated with UVB exposure (WORLD EDUCATION, 2013).

Each individual has a sensitivity to ultraviolet radiation, depending mainly on their skin type, relating to how long the individual can be exposed. In general, darker skin is more tolerant. Stressing that the skin type is a genetic factor, and cannot be modified by the action of physical agents (such as artificial tanning) and chemical products (such as suntan lotions, which are not considered sunscreens) (CETESB, 2020). Considering erythema and pigmentation, Brazilian skin can be classified according to Table 1 below.

Table 1. Fitzpatrick phototypes (MOTA et al., 2005; SBD, 2023).

Fototipos	Descrição	Sensibilidade ao sol
I – Branca	Pele muito branca, cabelo em geral ruivo. A pele queima facilmente e dificilmente bronzeia.	Muito sensível
II – Branca	Pele branca, cabelos loiros e olhos claros. A pele queima facilmente e bronzeia moderada e uniformemente.	Sensível
III – Morena Clara	Pele branca, cabelos castanho-escuros ou pretos. A pele queima e bronzeia moderada e uniformemente.	Normal
IV – Morena Moderada	Pele clara ou bege, incluindo pessoas orientais. A pele queima pouco, mas bronzeia fácil e moderadamente.	Normal
V – Morena Escura	Pele parda escura ou marrom médio (pessoas mulatas). Queima raramente, bronzeia muito e mancha com facilidade.	Pouco sensível
VI – Negra	Pele totalmente pigmentada (negra). Nunca queima, bronzeia muito e mancha com facilidade.	Resistente

Influencing Factors:

- **Time:** The day can be divided into three times: morning, noon, and afternoon. The solar noon is the most critical condition, that is, the time when one should be less exposed to the sun, especially for children and newborns.
- **Location:** Due to the geographical position, the locations have different average solar radiation levels. On the website of the National Institute of Meteorology (INMET) it is possible to see the solar radiation of all the observed municipalities in Brazil. Altitude has a direct relationship, because higher locations are more exposed to this radiation.
- **Exposure conditions:** Another factor refers to the climatic condition of the region (clear sky, without clouds, rain, etc.), which varies during the year, so the maximum time recommended for direct sun exposure can be altered. Remember that even on days with less sun visibility, indirect radiation occurs, with cloudy skies also affecting the skin. The type of ground cover also influences the exposure time, concrete tends to store more heat, vegetation helps to dissipate it. Conditions such

as reflective surfaces like dry sand and water increase radiation exposure, therefore decreasing the recommended time. As a preventive method the use of physical barriers (such as clothing, sunshades or sunblocks) reduce UV exposure, and may increase the exposure time.

6 SOLAR RADIATION IN SALVADOR

The data used in the research were taken from the INMET website. A Figure 2 contains the average solar irradiation and

Figure **3** the average temperature for the city of Salvador - BA in the period from January 01, 2021 to December 31, 2021. The data acquisition was successful because during the year 2021 there were no breakdowns in the meteorological stations of the city. When observing the radiation we can observe a decrease between April and July, characterized by winter in the northeast region, and a large radiation between January and March, represented by summer. Similarly, the average temperature has lower values in the winter months and higher in the summer. These are factors that should be observed when asked about the ideal exposure time for each individual, given the other factors mentioned above (skin color, age, physical barriers, etc.).

Figure 2. Solar radiation in Salvador.

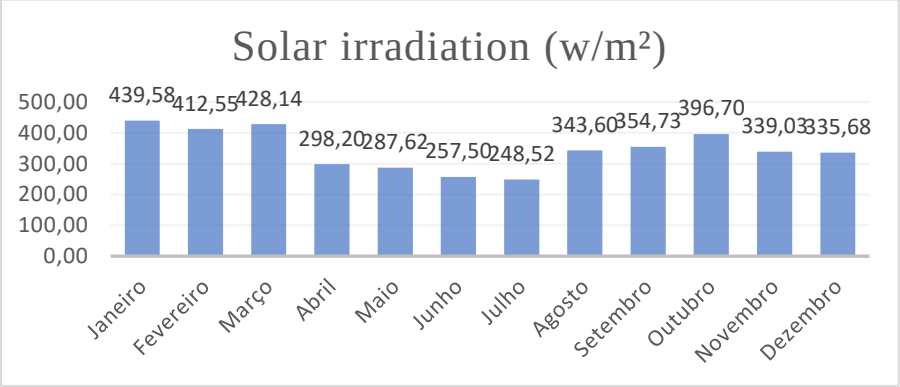
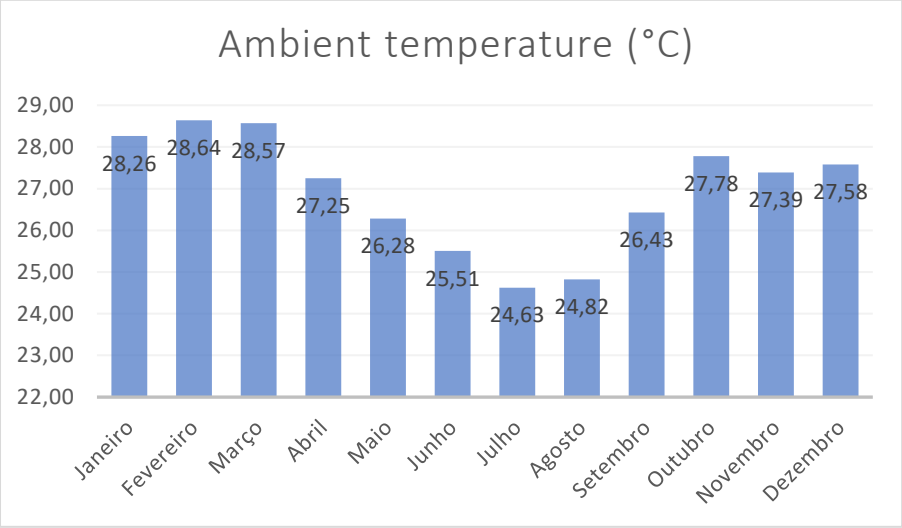


Figure 3. Ambient temperature in Salvador.



If we separate the solar irradiation by weather stations, we see that the seasons that have the most solar radiation are: summer (between the end of December and the end of March), spring (September to December), decreasing in the fall (between March and June), accentuating the fall at the beginning of winter, but recovering the average already in August. It is possible to see that the peak of solar radiation is concentrated between 10 am and 2 pm, which is also the time when sun exposure is not recommended.

With a 95% confidence interval (CI) the following table was elaborated

Table 2 with the data of solar radiation for Salvador for a month by month analysis, it is noted that in the first semester January had the highest average solar radiation 473W/m² and in the second October with 427W/m², demonstrated quarterly in

Figure **4**. If an individual of the same type, exposed to the same place under the same conditions, in these months he would receive more solar radiation than in the other months, considering the average solar radiation, because factors such as hours of exposure, time of day, and physical barriers need to be accounted for. As an example of preventive protection, it would be recommended that maintenance and installation of solar panels take place outside the demonstrated peak hours.

Figure 4. Solar radiation in Salvador by quarter.

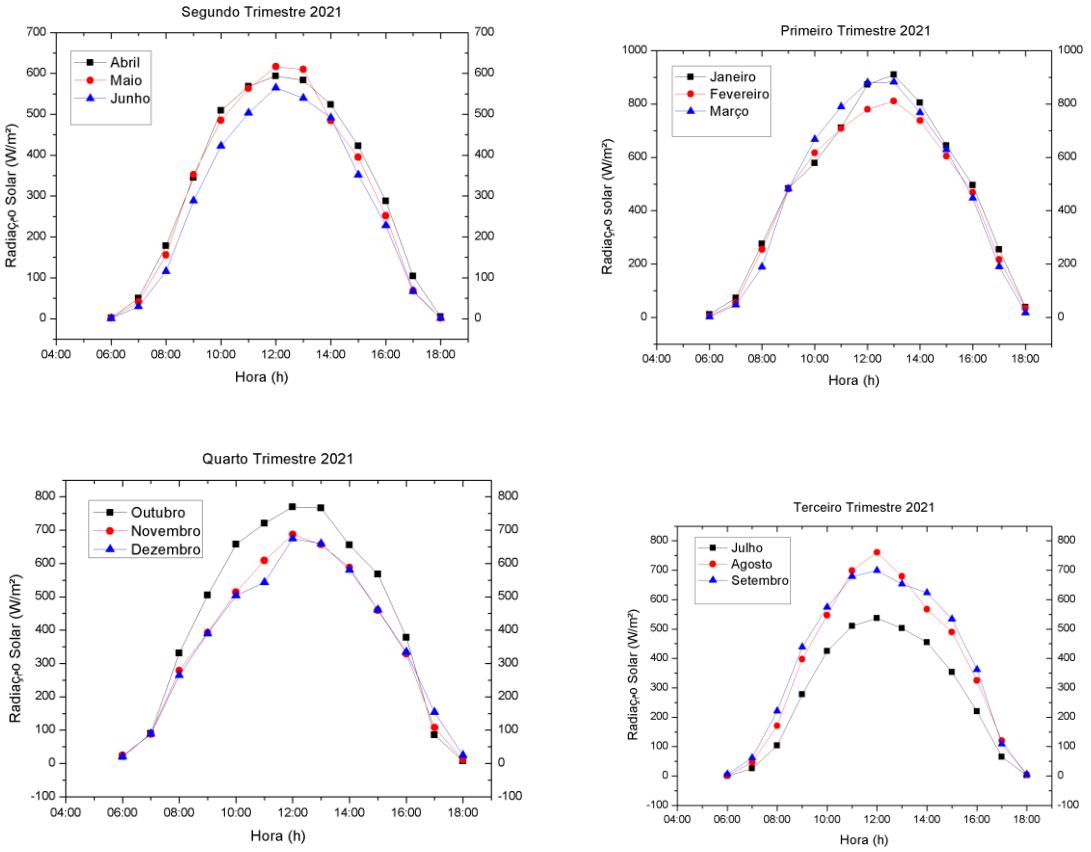


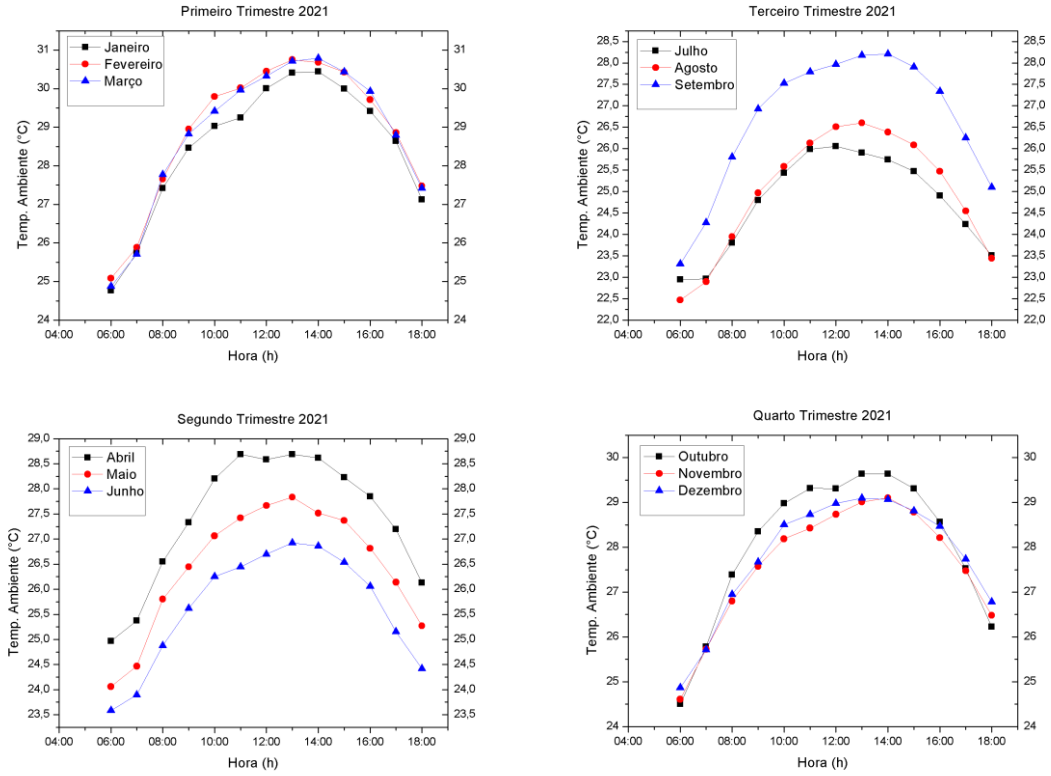
Table 2. Solar radiation with confidence interval and standard deviation.

1st Quarter	**January**	**February**	**March**
Average Radiation (W/m²) =	473,39	444,28	461,07
Standard Deviation =	317,08	297,00	335,70
Standard Deviation from Mean =	87,94	82,37	93,10
Confidence Interval (CI) =	473±87,94	444,28±82,37	461,07±93,10
Total Radiation (W/m²) =	6154,11	5775,73	599,94
2nd Quarter	**April**	**May**	**June**
Average Radiation (W/m²) =	321,14	309,74	277,30
Standard Deviation =	230,03	235,69	216,47
Standard Deviation from Mean =	63,79	65,37	60,03
Confidence Interval (CI) =	321,14±63,79	309,74±65,37	277,30±60,03
Total Radiation (W/m²) =	4174,84	4026,70	3605,00
3rd Quarter	**July**	**August**	**September**
Average Radiation (W/m²) =	267,63	370,03	382,01
Standard Deviation =	209,1	276,86	269,19
Standard Deviation from Mean =	57,99	76,78	74,66
Confidence Interval (CI) =	267,63±57,99	379,03±76,78	382,01±74,66
Total Radiation (W/m²) =	3479,31	4810,42	4966,23

4th Quarter	October	November	December
Average Radiation (W/m²) =	427,22	365,1	361,49
Standard Deviation =	293,47	245,51	233,85
Standard Deviation from Mean =	81,39	68,09	64,85
Confidence Interval (CI) =	427,22±81,39	365,1±68,09	361,49±64,85
Total Radiation (W/m²) =	5553,87	4746,36	4699,49

In parallel with solar radiation, the average ambient temperature showed similar behavior at peak hours, between 10 a.m. and 2 p.m. of the observed period (Figure 5). The highest average temperature was observed in February and October. October was the month with the second highest radiation and the second highest average temperature, the exposure time should be reassessed for individuals (depending on their skin type, as seen previously). But beforehand it would be a month to reinforce caution, like all the months of spring and summer, which showed high average ambient temperature and high average solar radiation.

Figure 5. Ambient temperature by quarter Salvador.



The Table 3 helps in the analysis and reinforces that the rainy months, no matter how small the solar radiation was, the temperature variation was considered small when it comes to the average ambient temperature, reinforcing that on cloudy days there is an incidence of solar radiation, therefore, ultraviolet radiation.

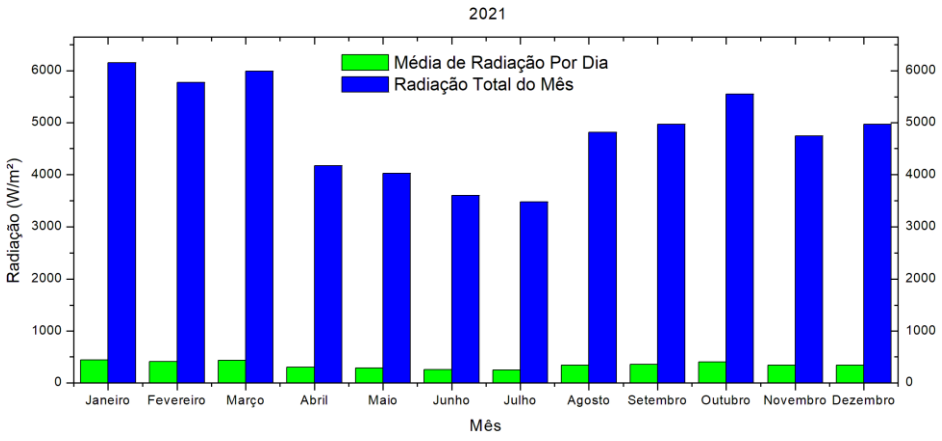
Table 3. Ambient temperature with confidence interval and standard deviation.

1st Quarter	**January**	**February**	**March**
Temp. Average Ambient Temp (°C) =	28,51	28,90	28,84
Standard Deviation =	1,78	1,85	1,90
Standard Deviation from Mean =	0,49	0,51	0,52
Confidence Interval (CI) =	28,51±0,49	28,9±0,51	28,84±0,52
2nd Quarter	**April**	**May**	**June**
Temp. Average Ambient Temp (°C) =	27,41	26,45	25,64
Standard Deviation =	1,29	1,23	1,14
Standard Deviation from Mean =	0,35	0,34	0,31
Confidence Interval (CI) =	27,41±0,35	26,45±0,34	25,64±0,31
3rd Quarter	**July**	**August**	**September**
Temp. Average Ambient Temp (°C) =	24,75	25,00	26,66
Standard Deviation =	1,14	1,42	1,60
Standard Deviation from Mean =	0,31	0,39	0,44
Confidence Interval (CI) =	24,75±0,31	25±0,39	26,66±0,44
4th Quarter	**October**	**November**	**December**

Temp. Average Ambient Temp (°C) =	28,04	27,62	27,79
Standard Deviation =	1,65	1,37	1,36
Standard Deviation from Mean =	0,45	0,38	0,37
Confidence Interval (CI) =	28,04±0,45	27,62±0,38	27,79±0,37

In order to Figure 6 shows the average total solar radiation and also the average solar radiation of the day for each month of the observed period. There is a variation among the months, with some showing a high solar radiation (January to March) and others (April - July) showing a period of low solar radiation, relating the solar radiation to the summer and winter seasons of the observed city. The same behavior can be seen in the average radiation per day in these months. It is once again evident that in the first semester January has the highest solar radiation, although it is slightly above March. And in the second semester October stands out, both in total radiation and average daily radiation. The data used could also demonstrate the months with the highest photovoltaic energy production capacity.

Figure 6. Total and average radiation for Salvador.



7 CONCLUDING REMARKS

Solar radiation has pros and cons, if from the energy point of view it is a power to be harnessed, from the health point of view there has to be caution. Factors such as location, exposure, skin type, among others, imply damage that can cause cancer (usually associated with UVB rays).

The ozone layer protects us from UVA rays and UVC rays are in our daily lives, helping to release vitamins and also being used to produce energy by converting solar energy into electrical energy.

Observing Salvador, it was noticed a higher increase in solar radiation in the months between spring and summer, months that also have the highest average temperatures. There is a higher risk of cases favoring burns and skin cancer in this period, so a greater care by the government and the population with these months is necessary.

But not forgetting that in winter months, even with little radiation, the average temperature was only 2°C below in some months, reinforcing the incidence of sunlight even on cloudy days, physical barriers (clothing, hats, etc.) and artificial barriers (sunscreen) should always be used and provided for anyone who will spend a longer than recommended time under the sun, always observing the peak hours.

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