International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2020.33681

Volume 6, Issue 1
January - 2020

Comparative Study on Mass loss by the Sun and Energy Available for Utilization between two Tropical Stations in Nigeria

Davidson Odafe Akpootu[1*], Simeon Imaben Salifu[2], Okpala Chidozie Nnaemeka[3], Samuel Adesina Fagbemi[4], Mukhtar Isah Iliyasu[5], Shaibu Aruna[6] and Isaac Obiajulu Onwubuya[7]

[1]Department of Physics, Usmanu Danfodiyo University, Sokoto, Nigeria

[2]Department of Physics, Kogi State College of Education Technical Kabba, Nigeria

[3]Department of Physics, Federal University Dutsin-ma, Katsina, Nigeria

[4]Department of Physics, Ahmadu Bello University, Zaria, Nigeria

[5]Physics Unit, Umaru Ali Shinkafi Polytechnic, Sokoto, Nigeria

[6]Department of Science, La Salle College, Ondo, Nigeria

[7]Airforce Institute of Technology, Kaduna, Nigeria

ABSTRACT

The electromagnetic radiation emitted from the Sun is called solar radiation. Almost all life on Earth evolved with the Sun as a major influence. The rising and setting Sun defined the daily cycle we still respond to biologically. This study investigates the yearly, monthly and daily variation of mass loss by the Sun for two locations; Gusau and Calabar situated across the Sahelian and Coastal climatic zones of Nigeria using daily, monthly and yearly global solar radiation meteorological data obtained from the National Aeronautics and Space Administration (NASA) during the period of twenty two years (July 1983 – June 2005). The energy available for utilization based on the mass loss by the Sun for the two locations was also investigated. The fluctuations in the results revealed that the mass loss by the Sun varies significantly from year to year, month to month and from day to day; thus, indicating that it is site dependent and strongly depends on the global solar radiation and solar activities in each of the locations. The highest yearly, monthly and daily mass losses by the Sun for Gusau are 6.3155×10^{17} kg y^{-1}in 1985, 5.5691×10^{16} kg m^{-1} in April and 2.3482×10^{15} kg d^{-1} on April 21, 1985 respectively and the lowest yearly, monthly and daily mass losses by the Sun are 5.6423×10^{17} kg y^{-1}in 1999, 4.2740×10^{16} kg m^{-1}in December and 1.3031×10^{15} kg d^{-1} on December 25, 1999 respectively. The highest yearly, monthly and daily mass losses by the Sun for Calabar are 4.6558×10^{17} kg y^{-1} in 1984, 4.6451×10^{16}kg m^{-1} in February and 2.0252×10^{15} kg d^{-1} on February16, 1984 respectively and the lowest yearly, monthly and daily mass losses by the Sun are3.6806 $\times 10^{17}$ kg y^{-1} in 1983, 2.5346×10^{16} kg m^{-1}in August and 1.9546×10^{14} kg d^{-1} on August7, 1983 respectively. The results indicated that the solar energy available for utilization for Gusau are greater than that of Calabar and this is a reflection of the abundant amount of global solar radiation received on a horizontal surface for Gusau as compared to Calabar.

Keywords: Mass loss, Sun, Solar energy utilization, Global solar radiation, NASA.

1. INTRODUCTION

The Sun is the star closest to the earth, and its radiant energy is practically the only source of energy that influences atmospheric motions and our climate [1]. The Sun is a completely gaseous body composed mainly of hydrogen [1]. Its physical structure is complex and composed of several regions: the core, the interior, the convecting zone, the photosphere, the reversing layer, the chromosphere, and the corona [1]. The core is the innermost region and is the sun's hottest and densest part. The temperature of the core ranged from 15 x 10^6 to 40 x 10^6 K and is composed of highly compressed gases at a density of 100-150 g/cm^3 [1]. Above the core is the interior, which contains practically all of the Sun's mass; the core and the interior are thought of as a huge nuclear

Licensed Under Creative Commons Attribution CC BY-NC

Corresponding Author: davidson.odafe@udusok.edu.ng

reactor and the source of almost all its energy. This energy is propagated mainly by radiation to the outer regions, which in turn transport this energy outward by convection and reradiation [1]. The surface of the Sun is called the photosphere, is the source of most visible radiation arriving at the earth's surface. This is the "crust," which can be seen through a blue glass by the naked eye. It is composed of very low-density inhomogeneous gases that form granulations and sunspots [1].The photosphere is the visible layer of the Sun, about 100 km thick [2]. Sunspots can be viewed in this layer, and the rotation of the Sun was first detected when the motion of these sunspots was observed [2].The temperature in this region is 4000-6000 K. The reversing layer extends for a few hundred kilometers: this layer contains vapors of almost all the familiar elements of the earth's crust. Above it, extending over a distance of about 2500 km, is the chromosphere, which, with the reversing layer, forms the sun's atmosphere. Composed mainly of hydrogen and helium, it is visible to the naked eye during an eclipse [1]. The relatively thin layer of the Sun called the chromosphere is sculpted by magnetic field lines that restrain the electrically charged solar plasma [2].The temperature of the chromosphere is several times higher than that of the photosphere [1]. The outermost portion of the sun is called the corona and is composed of extremely rarefied gases called the solar winds, which are thought to extend into the solar system. The coronal gases are considered to be at temperatures several times those of the photosphere [1].

The solar mass is a standard unit of mass in astronomy, equal to approximately $2 \times 10^{30}\ kg$. It is used to indicate the masses of other stars, as well as clusters, nebulae and galaxies. It is equal to the mass of the Sun [3 – 4]. Sir Isaac Newton was the first person to estimate the mass of the Sun [5]. In his work *Principia* (1687), he estimated that the ratio of the mass of Earth to the Sun was about 1/28 700. The mass of the Sun has been decreasing since the time it formed. As the Sun loses mass its gravitational pull on the planets weakens slightly [6]. The Sun can't hold the planets as strongly as it used to, so the planets drift a bit further away from the Sun. At least that's the theory [6]. The shift of the planets is so small that it's difficult to measure [6].

The Sun loses mass in two major ways. The first is through solar wind. The surface of the Sun is hot enough that electrons and protons boil off its surface and stream away from the Sun, generating a “wind” of ionized particles [7]. When those particles strike Earth’s upper atmosphere they can produce aurora [7]. The solar wind varies a bit in intensity, but from satellite observations, it is known that the Sun loses about 1.5 million tonnes of material each second due to solar wind [7].

The second way the Sun loses mass is through nuclear fusion [7]. The Sun is powered by the conversion of hydrogen into helium in its core, through the process of nuclear fusion [8] producing its life-giving glow over billions of years [7]. The production of helium transforms some of the hydrogen’s mass into energy, which radiates away from the Sun in the form of light and neutrinos [7].This reaction results in a decrease in the Sun’s mass, and in the release of energy through electromagnetic radiation and the solar wind [9]. By observing just how much energy the Sun radiates, and using Einstein’s equation relating mass and energy, it was found that the Sun loses about 4 million tonnes of mass each second due to fusion [7].

So the Sun loses about 5.5 million tonnes of mass every second or about 174 trillion tonnes of mass every year [7]. That’s a lot of mass, but compared to the total mass of the Sun it’s negligible. The Sun will keep shining for another 5 billion years, and by that time it will have lost only about 0.034% of its current mass [7]. Several studies has been carried out by different researchers to calculate the mass loss by the Sun, this include Zuber and Smith [8], Kippenhahn [10] and Cox [11] to mention but a few.

The purpose of this study is to estimate and compare the mass loss by the Sun for Gusau and Calabar situated across the Sahelian and Coastal regions of Nigeria. The estimated mass loses for the locations were compared to those available in literatures. The study also investigates and compared the energy available for utilization based on the mass loss for the locations under investigation.

2. METHODOLOGY

The measured daily climatic data of global solar radiation utilized in this present work were obtained from the National Aeronautics and Space Administration (NASA) atmospheric science data centre under Surface meteorology and Solar Energy. The daily averaged data were aggregated to monthly data. Similarly, the monthly averaged data were aggregated to yearly data. The study area under investigation is Gusau (Latitude 12.17^0N, Longitude 6.70^0E and altitude 463.9 m above sea level) located in Sahelian zone of Nigeria and Calabar (Latitude 4.97^0N, Longitude 8.35^0E and altitude 61.9 m above sea level) located in the Coastal zone of Nigeria. To avoid possible misleading indications related to year to year variation in weather condition, the period under investigation is twenty two years (July 1983 – June 2005) so as to obtain a good climatological average. The quality assurance of the meteorological measurements was determined by checking the overall consistency of the daily, monthly and yearly average of the meteorological parameter used in the study areas. According to Olaniran [12] Nigeria is classified into four climatic zones; these are the Sahelian zone, Midland zone, Guinea savannah zone and the Coastal zone. The locations within the climatic zones are shown in Figure 1.

DOI: 10.31695/IJASRE.2020.33681

Figure 1. Map of Nigeria showing the locations under investigation

The area, A in m^2 of spherical shell centered on the Sun and passing through the Earth is given by [13]

$$A = 4\pi r^2 \qquad (1)$$

where r is the radius of the Earth from the Sun and is numerically given as $r = 1.50 \times 10^{11}\ m$.

The radiation per second in $Watts\ (W)$ emitted from the Sun to a specific location on the Earth's surface is given by

$$radiation/second = A \times station's\ radiation \qquad (2)$$

The energy radiated in one day, in $Joules\ (J)$ is given by

$$energy/day = radiation/second \times 86400 \qquad (3)$$

The energy radiated in one month, in $Joules\ (J)$ is given by

$$energy/month = radiation/second \times 2592000 \qquad (4)$$

The energy radiated in one year, in $Joules\ (J)$ is given by

$$energy/year = radiation/second \times 31536000 \qquad (5)$$

From the famous Einstein's mass energy relation [13], the mass loss by the Sun per day is given by

$$m_{loss} = \frac{energy/day}{c^2} \qquad (6)$$

The mass loss by the Sun per month is given by

$$m_{loss} = \frac{energy/month}{c^2} \qquad (7)$$

The mass loss by the Sun per year is given by

DOI: 10.31695/IJASRE.2020.33681

$$m_{loss} = \frac{energy/year}{c^2} \quad (8)$$

where$c$ is the speed of light and is numerically given as $c = 3 \times 10^8\ ms^{-1}$

3. RESULTS AND DISCUSSION

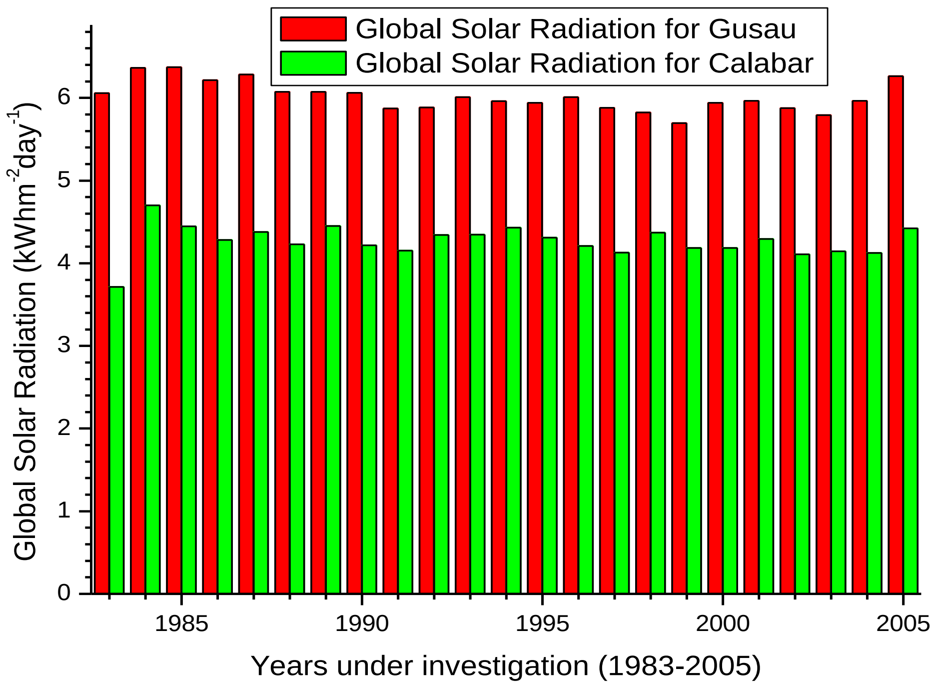

Figure2. Comparison between the measured yearly averaged global solar radiation for Gusau and Calabar

Figure 2 shows the yearly variation of global solar radiation for Gusau and Calabar during the period under investigation. The figure shows that Gusau received the highest amount of global solar radiation in all the months as compared to Calabar. The highest value of global solar radiation for Gusau was in the year 1985 with 6.3738 $kWhm^{-2}day^{-1}$ and the lowest value in the year 1999 with 5.6944 $kWhm^{-2}day^{-1}$. The highest value of global solar radiation for Calabar was in the year 1984 with 4.6988 $kWhm^{-2}day^{-1}$ and the lowest value in the year 1983 with 3.7145 $kWhm^{-2}day^{-1}$.

DOI: 10.31695/IJASRE.2020.33681

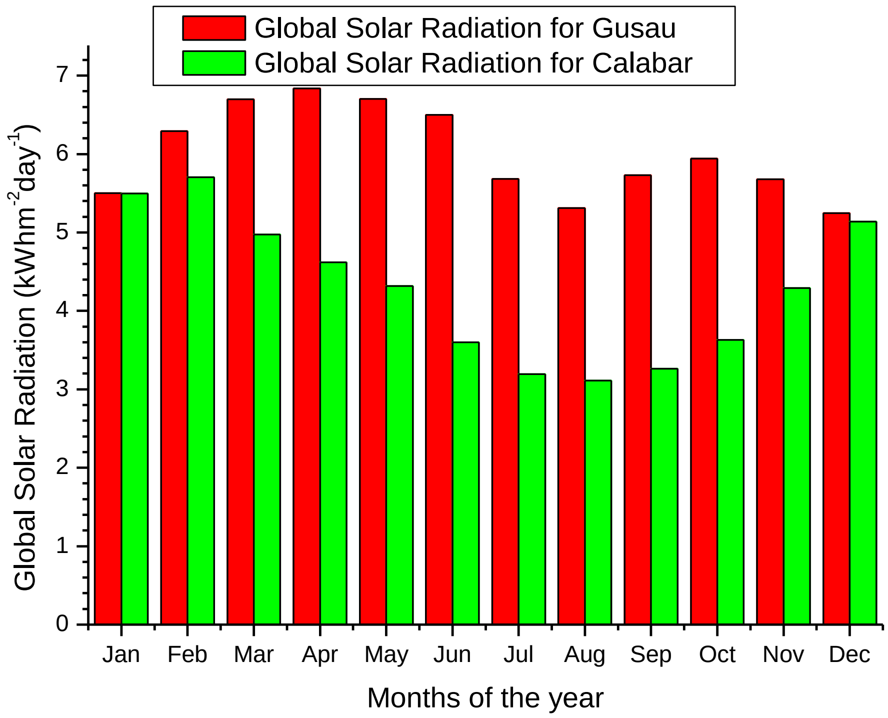

Figure 3. Comparison between the measured monthly averaged global solar radiation for Gusau and Calabar

Figure 3 shows the monthly variation of global solar radiation for Gusau and Calabar during the period under investigation. It was observed that Gusau received the highest amount of global solar radiation in all the months as compared to Calabar except in January where they both have almost the same value of global solar radiation; though, that of Gusau is slightly higher with 0.0017 $kWhm^{-2}day^{-1}$. The highest value of global solar radiation for Gusau was in the month of April with 6.8382 $kWhm^{-2}day^{-1}$ and the lowest value in the month of December with 5.2479 $kWhm^{-2}day^{-1}$. The highest value of global solar radiation for Calabar was in the month of February with 5.7036 $kWhm^{-2}day^{-1}$ and the lowest value in the month of August with 3.1123 $kWhm^{-2}day^{-1}$.

Figure 4. Variation of mass loss per year during the period under investigation for Gusau

DOI: 10.31695/IJASRE.2020.33681

Figure 4 shows the yearly variation of mass loss by the Sun for Gusau during the period under investigation. The result indicated that the mass loss varies significantly from year to year; the highest value of mass loss was in 1985 with $6.3155 \times 10^{17} kgy^{-1}$and the lowest was in 1999 with $5.6423 \times 10^{17} kgy^{-1}$.

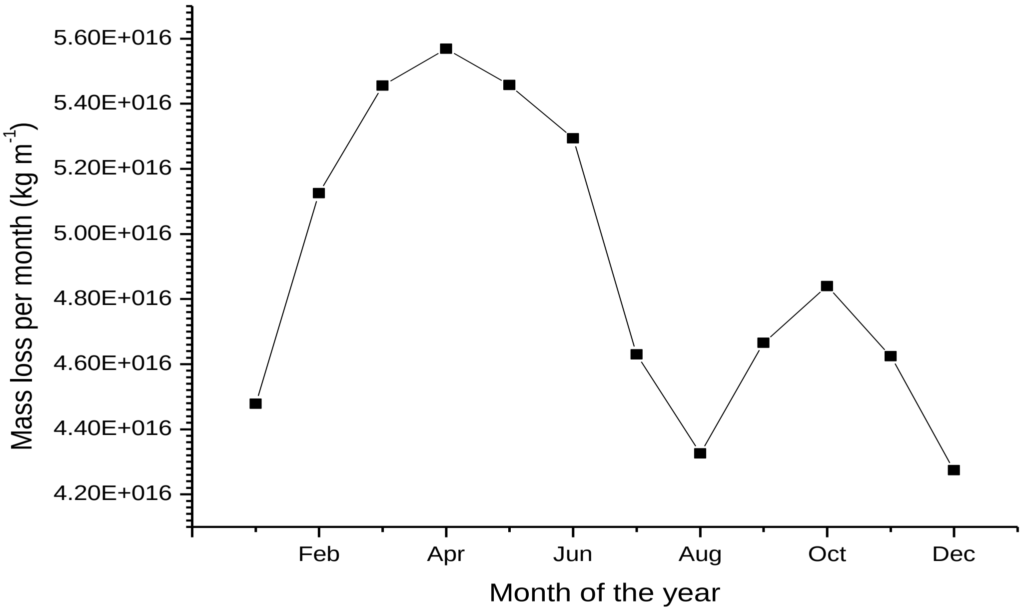

Figure 5. Variation of mass loss per month for Gusau

Figure 5 shows the monthly variation of mass loss by the Sun for Gusau. It is obvious that the highest mass loss was in the month of April with $5.5691 \times 10^{16} kgm^{-1}$ and the lowest in December with $4.2740 \times 10^{16} kgm^{-1}$.

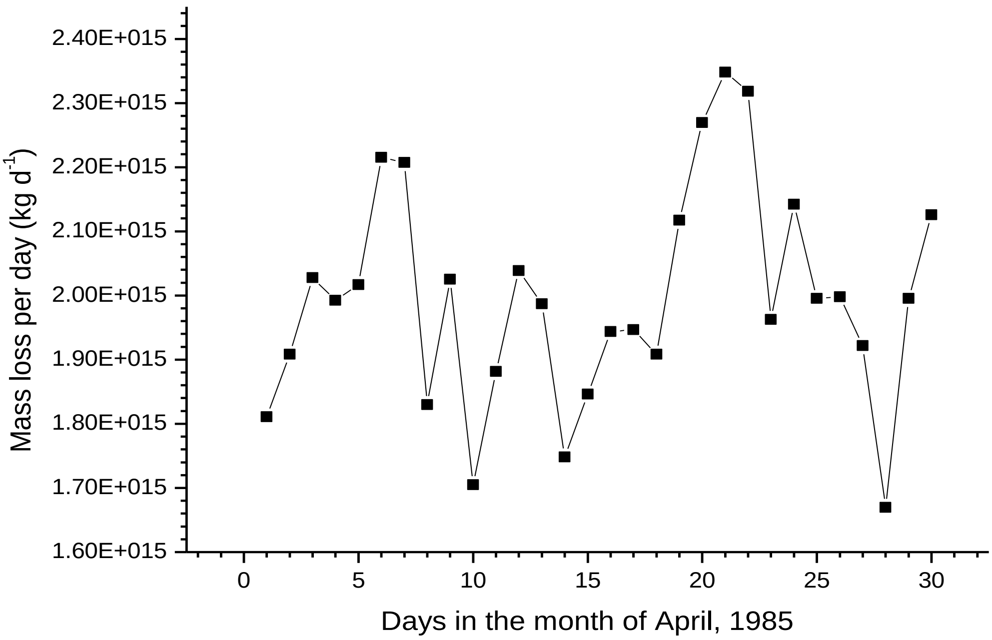

Figure 6. Variation of mass loss per day for the maximum month during the period of investigation for Gusau

Figure 6 shows the daily variation of mass loss by the Sun in April, 1985 for Gusau. It can be seen that the mass loss varies significantly from day to day with the highest value on April 21, 1985 with $2.3482 \times 10^{15} kgd^{-1}$ and the lowest value on April 28, 1985 with $1.6695 \times 10^{15} kgd^{-1}$.

DOI: 10.31695/IJASRE.2020.33681

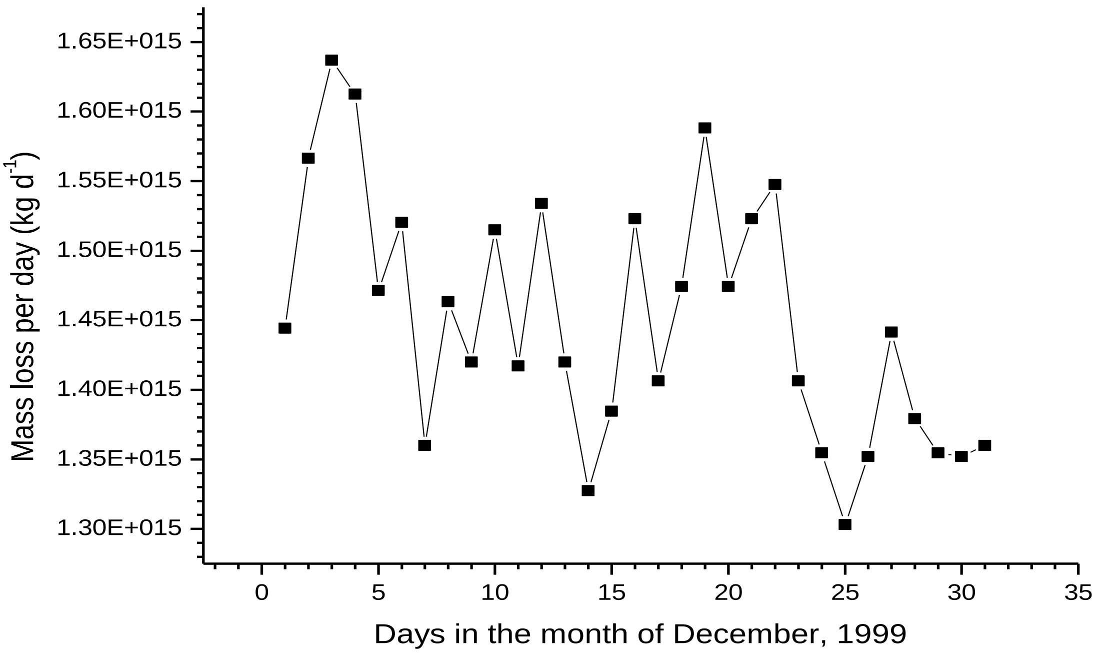

Figure 7. Variation of mass loss per day for the minimum month during the period of investigation for Gusau

Figure 7 shows the daily variation of mass loss by the Sun in December, 1999 for Gusau. It can be seen that the mass loss varies significantly from day to day with the highest value on December 3, 1999 with $1.6370 \times 10^{15} kgd^{-1}$ and the lowest value on December 25, 1999 with $1.3031 \times 10^{15} kgd^{-1}$.

Figure 8. Variation of mass loss per year during the period under investigation for Calabar

Figure 8 shows the yearly variation of mass loss by the Sun for Calabar during the period under investigation. The result indicated that the mass loss varies significantly from year to year; the highest value of mass loss was in 1984 with $4.6558 \times 10^{17} kgy^{-1}$ and the lowest was in 1983 with $3.6806 \times 10^{17} kgy^{-1}$.

DOI: 10.31695/IJASRE.2020.33681

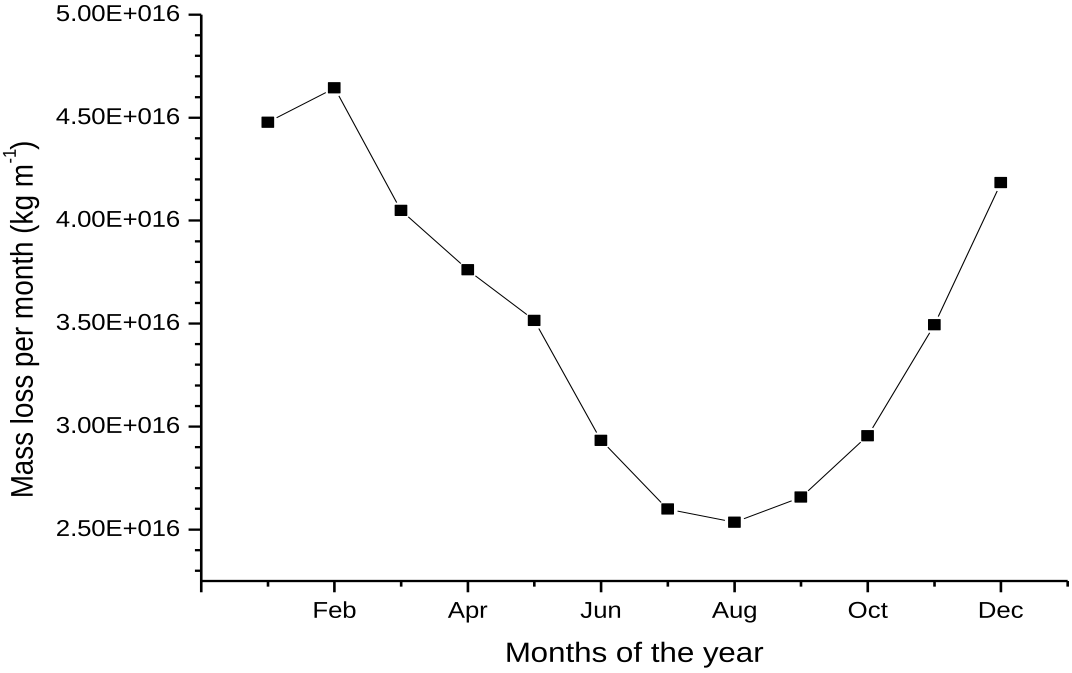

Figure 9. Variation of mass loss per month for Calabar

Figure 9 shows the monthly variation of mass loss by the Sun for Calabar. It is obvious that the highest mass loss was in the month of February with $4.6451 \times 10^{16} kgm^{-1}$ and the lowest in December with $2.5346 \times 10^{16} kgm^{-1}$.

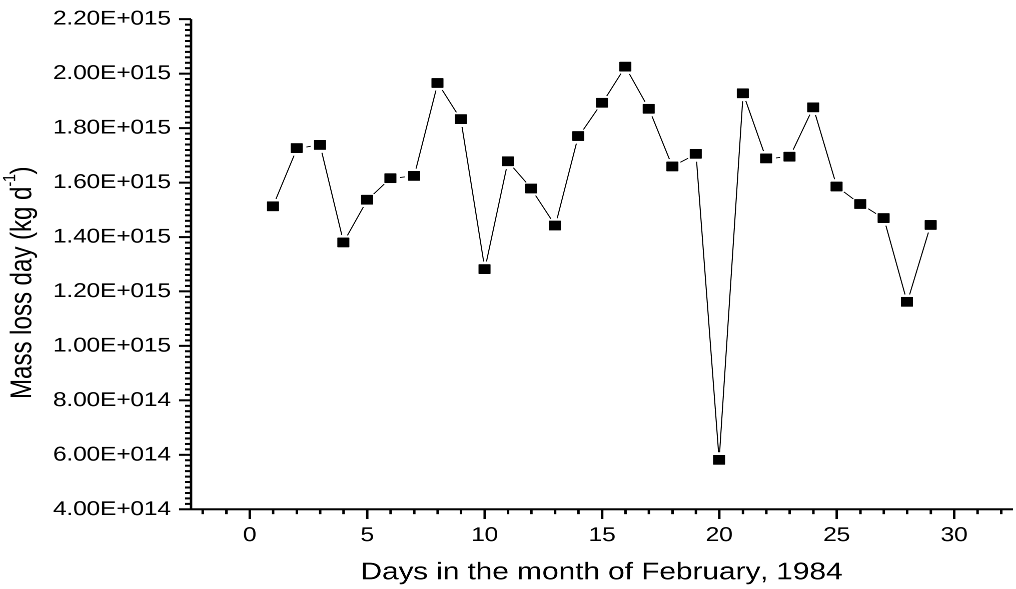

Figure 10. Variation of mass loss per day for the maximum month during the period of investigation for Calabar

Figure 10 shows the daily variation of mass loss by the Sun in February, 1984 for Calabar. It can be seen that the mass loss varies significantly from day to day with the highest value on February 16, 1984 with $2.0252 \times 10^{15} kgd^{-1}$ and the lowest value on February 20, 1984 with $5.8094 \times 10^{14} kgd^{-1}$.

DOI: 10.31695/IJASRE.2020.33681

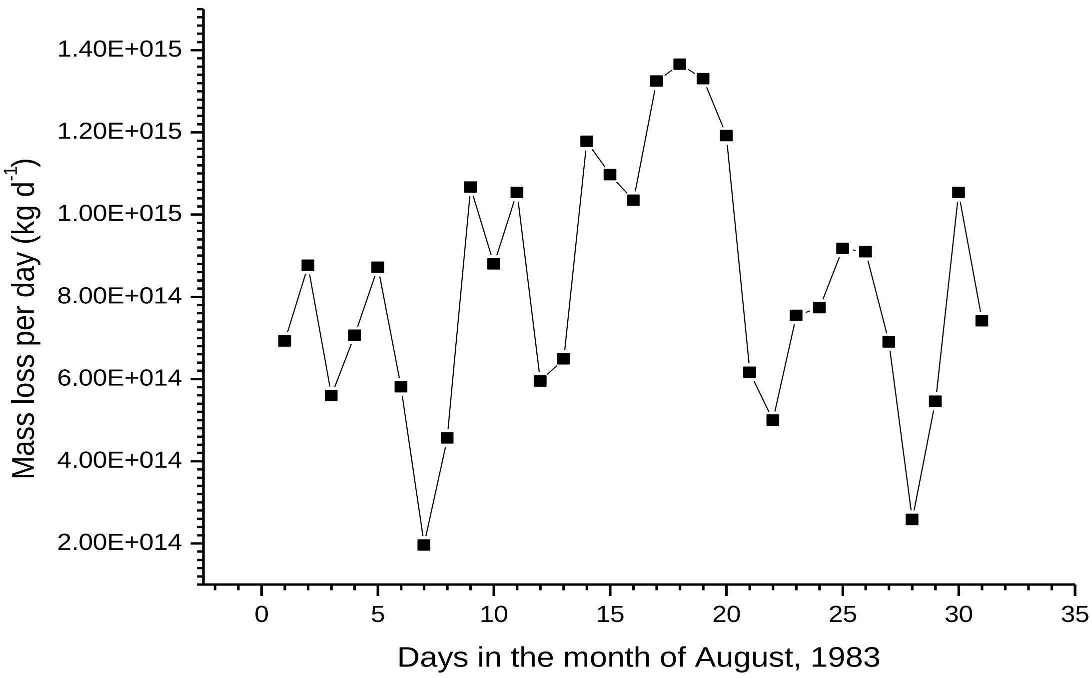

Figure 11. Variation of mass loss per day for the minimum month during the period of investigation for Calabar

Figure 11 shows the daily variation of mass loss by the Sun in August, 1983 for Calabar. It can be seen that the mass loss varies significantly from day to day with the highest value on August 18, 1983 with $1.3655 \times 10^{15} kgd^{-1}$ and the lowest value on August 7, 1983 with $1.9546 \times 10^{14} kgd^{-1}$.

In this study, the highest and lowest yearly values of mass loss by the Sun for Gusau are $6.3155 \times 10^{17} kgy^{-1}$ in 1985 and $5.6423 \times 10^{17} kgy^{-1}$ in 1999 respectively while for Calabar are $4.6558 \times 10^{17} kgy^{-1}$ in 1984 and $3.6806 \times 10^{17} kgy^{-1}$ in 1983 respectively. The results in this study are in line with those reported by Zuber and Smith [8] where they evaluated the mass loss by the Sun in one year to be $4.44 \times 10^{16} kgy^{-1}$. Kippenhahn [10], obtained the mass loss by the Sun in one year as $1.3530 \times 10^{17} kgy^{-1}$. In another study, Cox [11], estimated the mass loss by the Sun in one year as $1.3572 \times 10^{17} kgy^{-1}$.

4. CONCLUSION

This present study examines the yearly, monthly and daily variation of mass loss by the Sun and energy available for utilization in two locations; Gusau (Latitude 12.17^{0}N, Longitude 6.70^{0}E) located in Sahelian zone of Nigeria and Calabar (Latitude 4.97^{0}N, Longitude 8.35^{0}E) located in the Coastal zone of Nigeria using daily, monthly and yearly global solar radiation meteorological data obtained from the National Aeronautics and Space Administration (NASA) during the period of twenty two years (July 1983 – June 2005). The highest and lowest values of mass losses for the two locations considered are in close agreement with those reported in literature e.g., Zuber and Smith [8], Kippenhahn [10] and Cox [11] with the mass loss by the Sun for Gusau been higher than that of Calabar. However, the results in this study suggests that the mass loss by the Sun varies significantly from year to year, month to month and from day to day rather than having a single point value, therefore, indicating that the mass loss by the Sun is strongly dependent on the global solar radiation and solar activities of the location/region as it is site dependent. The energy available for utilization using the famous Einstein's mass energy equation as a direct relationship that exist with the mass loss by the Sun revealed that the solar energy available for utilization for Gusau are greater than that of Calabar and this is a reflection of the abundant amount of global solar radiation received on a horizontal surface for Gusau as compared to that of Calabar.

ACKNOWLEDGEMENTS

The authors wish to appreciate the management and staff of the National Aeronautics and Space Administration (NASA) atmospheric science data centre under Surface meteorology and Solar Energy for making all the relevant data used in this present study available online. The contribution and suggestions of the anonymous reviewers are well appreciated.

DOI: 10.31695/IJASRE.2020.33681

REFERENCES

[1]]Iqbal, M (1983). An introduction to solar radiation, first ed. Academic Press, New York.

[2] Butcher, G., Mottar, J and Smith, C. C. (2019). Mysteries of the Sun, Presented by NASA'S Heliophysics Division of the Science Mission Directorate.

[3] "Astronomical Constants" (PDF).The Astronomical Almanac.2014. p. 2.Retrieved April 10, 2019.

[4] "Newtonian constant of gravitation". Physical Measurement Laboratory.Retrieved April 10, 2019.

[5] Bernard, C. I. (1998). "Newton's Determination of the Masses and Densities of the Sun, Jupiter, Saturn, and the Earth".Archive for History of Exact Sciences.,**53** (1): 83–95.doi:10.1007/s004070050022.JSTOR41134054

[6] Antonio, G et al. (2018). "Solar system expansion and strong equivalence principle as seen by the NASA MESSENGER mission."Nature communications 9.1: 289.doi: 10.1038/s41467-017-02558-1

[7] Koberlein, B. (2015). Is The Sun Losing Mass? Accessed online on November 20, 2019.

[8] Zuber, M. T and Smith, D. E (2017). Measuring Solar Mass loss and Internal Structure from Monitoring the Orbits of the Planets.*Lunar and Planetary Science*., XLVIII (2017)

[9] Mullen, D. J. (2009). *Physics of the Sun: A First Course,* 390 pp., Chapman and Hall/CRC, Boca Raton.

[10] Kippenhahn, R. (1994). *Discovering the Secrets of the Sun,* Wiley Press.

[11] Cox, A. N. (2002). *Allen's Astrophysical Quantities, 4th Edition,* 721 pp., Springer, NY.

[12] Olaniran, O. J (1983). The Monsoon factor and the seasonality of rainfall distribution In Nigeria, Malaysian J Trop Geog, 7: pp 38 – 45.

[13] Bueche, F. J and Hecht, E (2006). College Physics, tenth edition. McGraw-Hill companies, .Pp 390 – 397.

DOI: 10.31695/IJASRE.2020.33681