AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 4, Issue 03, 2026 ISSN (E): 2993-2637

Assessment of the Impacts of Atmospheric Temperature and Pressure on Solar Irradiance in Idah, Kogi State, Nigeria

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Abstract: This study assessed the impacts of atmospheric temperature and pressure on solar irradiance in Idah, Kogi State, Nigeria. That data of atmospheric temperature and pressure were collected hourly from 9:00 am to 6:00 pm on February 25, 2026, in a school called Mathson School, Idah, using a weather station, while solar irradiance was measured using a pyranometer software installed on a laptop, and connected to the internet. The results revealed that the solar irradiance varied throughout the day, with peak values occurring in the early afternoon, which corresponds to higher temperatures and lower atmospheric pressures. The correlation analysis showed that there was a weak positive relationship between temperature and solar irradiance ($r = 0.065$) and a very weak negative relationship between pressure and solar irradiance ($r = -0.036$). This correlation despite the weak relationship shows that the solar irradiance is directly proportional with the atmospheric temperature and inversely with the atmospheric pressure. These findings demonstrate that atmospheric conditions have influence on solar irradiance and this provide insight into local solar energy potential. In addition, the results provide an insight regarding the period of time in which higher solar energy is expected in this research area, Idah, Kogi state. It was concluded that though, the correlation coefficients between the solar irradiance with the atmospheric temperature and pressure are low, there exists a relationship between solar irradiance and the two atmospheric parameters considered in this work. It is recommended that solar energy systems in Idah be designed to utilize peak solar irradiance periods between 11:00 am and 3:00 pm. It is also recommended that data of many days or months be used for the similar work in future. Additionally, continuous monitoring of atmospheric parameters should be implemented for improved solar energy planning. This study is valuable as it will inform solar energy forecasting, optimize solar panel placement, and enhance energy output predictions, supporting effective deployment of solar energy systems in the region.

Keywords: Energy, Global solar radiation, Pressure, Solar irradiance, Temperature.

1.0 Introduction

Solar irradiance is defined as the power of solar radiation received per unit area on a surface at a given instant. Studies have shown that solar radiation is the most important parameter in the design and evaluation of solar energy devices. An accurate knowledge of solar radiation distribution at a particular geographical location is very important in the surveys of agronomy, hydrology, ecology and sizing of the photovoltaic or thermal solar systems and estimates of their performances (Ituen, et.al. (2012)). As reported by Abdullahi (2017), an accurate knowledge of solar radiation distribution at a particular location is very useful in the sizing of the thermal solar systems to estimates their performances. The knowledge of when less solar radiation or solar energy will be less will aid in adequate planning such as having other backup power such to supplement for the insufficiency of the installed solar power system.

Simply put, the capacity to forecast periods of reduced solar radiation or solar energy will assist in effective planning, such as arranging alternative power sources like wind or hydroelectric power to compensate for the shortfall of the installed solar power system. As solar radiation travels through the atmosphere, it undergoes various changes. It is partly reflected, absorbed, and scattered by molecules, aerosols, water vapor, and clouds. Consequently, it is important to know how solar radiation interacts with other climate variables such as temperature and relative humidity towards developing better designs of solar arrays and mitigate the impact of climate variability (Ohiani, 2024). In the work by Etim et al. (2018), it was observed that the correlation analysis of solar radiation shows a positive relationship with temperature and evaporation; which implies that as temperature and evaporation increases, solar radiation also increases and vice versa. Also, the solar energy decreases as relative humidity and high rainfall increases; this indicates that relative humidity and rainfall have negative effect on the output of solar energy; which in turn limits the efficiency of solar Panels. Also, how much energy is obtained by the solar collector is to a large extent affected by weather conditions, such as time of year, seasonal changes in the angle of incidence of solar irradiance, length of day, cloud cover, humidity and the presence of airborne water vapor and aerosols that affect transparency and absorption properties of air (Omubo-Pepple et al, 2013 and Danuta et al, 2017). The main meteorological factors that have an influence on obtaining energy from the sun by collectors are: sunshine duration, radiation and total ambient air temperature (Dabrowski and Hutnik, 2015). But as reported by Etim et al. (2018), the high levels of humidity, rainfall-to-evaporation ration and evaporation per unit atmospheric temperature indicates that the amount of available solar energy depends on the amount of rainfall, humidity and the atmospheric temperature. Though, some works have been done on this topic or related topic, such work has not been done in dah, Kogi state, the gap this research work is meant to fill.

1.1 Definitions of some related terms

1.1.1. Solar Radiation

Solar radiation is defined as the electromagnetic energy emitted by the Sun, including visible light, ultraviolet, and infrared radiation, that reaches the Earth. The unit of Solar Radiation is W/m^2 (for instantaneous power), Joule (J) for total energy.

1.1.2. Solar Irradiance

Solar irradiance is the power of solar radiation received per unit area on a surface at a given instant. Solar irradiance can be measured on Earth or in space. On Earth, measurements are affected by atmospheric conditions, the position of the sun in the sky, and the angle of the measuring surface. In space, distance from the sun primarily affects solar irradiance. However, the sun’s solar cycle contributes also.

Its unit is W/m^2. The formula is given as;

$G = P/A\ \eta$

Where: G = solar irradiance (W/m^2), P = power received (W), A = area exposed to sunlight (m^2), η is the efficiency of the solar panel

1.1.3. Global Solar Radiation

It is defined as the total solar radiation received on a horizontal surface, including direct and diffuse radiation. Its unit is W/m^2 (instantaneous), J/m^2 or kWh/m^2 (over time)

Its formula is given as:

E_global = G_global x A x t

Where: E_global = Total global solar energy (J or Wh), G_global = Global irradiance (W/m²), A = Area (m²), t = Exposure time (s or h).

1.1.4. Solar Power

Solar Power is defined as the rate at which solar energy is converted into usable energy. Its unit is Watt (W). The formula is given as: $P_O = G \times A \times \eta$

Where: G = solar irradiance (W/m²), A = area of the panel (m²), η = panel efficiency (unitless)

1.1.5. Solar Energy

Solar Energy is defined as the total energy received from the Sun over a period of time. The units of Solar Energy is Joules (J), Watt-hour (Wh), kilowatt-hour (kWh)

The formula is given as:

$E = G \times A \times t \times \eta$

Where: E = solar energy (J or Wh), G = Solar irradiance (W/m²), A = area (m²), t = exposure time (s or h), η = efficiency of the conversion system

1.2 Types of solar irradiance

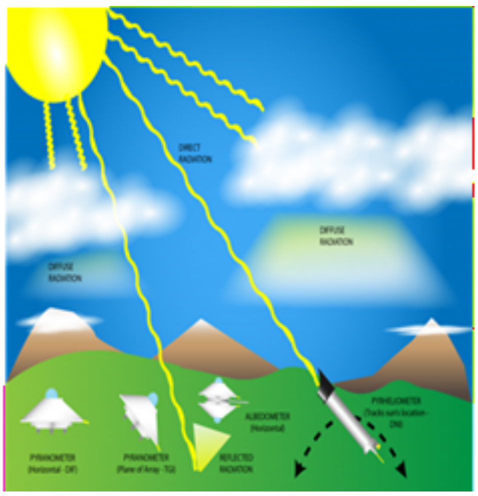
Direct Normal Irradiance (DNI): It is defined as the sunlight that hits the surface directly without scattering, essential for concentrated solar power systems.

Diffuse Horizontal Irradiance (DHI): It is defined as the sunlight scattered by clouds, dust, and molecules in the atmosphere, arriving from all directions.

Global Horizontal Irradiance (GHI): It is the total sum of direct and diffuse radiation, commonly used to assess overall solar potential.

Global Tilted Irradiance (GTI): It is the total radiation received on a surface with a specific tilt and azimuth, crucial for photovoltaic (PV) panel performance.

Reflected Irradiance: It is the sunlight that has bounced off the ground or surrounding objects before hitting the solar panel.



Types of solar irradiance

(Source: www.pubs.sciepub.com)

2.0 Research methodology

2.1 The study area

Idah, Kogi State, is situated in Northcentral Nigeria, near the confluence of the Niger and Benue rivers. The area features a mix of plains, hills, and plateaus. Idah has a tropical climate with two distinct seasons: the rainy season which is between April to September, and the dry season which is between October to March. The annual rainfall averages around 1,500 mm (59 inches), with the majority falling between June and September. In Idah, the hottest month is March, with average temperature of around of 33°C, while December is the coolest, with average temperature of around 20°C mostly due to harmattan. In addition, the vegetation of Idah's is made up of riverine vegetation with lush vegetation and aquatic plants, Savanna Grassland with tall grasses and scattered trees, and forest-Savanna Mosaic.

2.2 Materials

The research work made use of primary data which consisted of atmospheric temperature, atmospheric pressure and solar irradiance. The equipment used for the research were automatic weather station, pyranometer software, laptop, and watch.

2.3 Method

The experimental setup was done at Mathson Schools, Idah, Kogi State, Nigeria. The hourly measurements of atmospheric temperature and pressure were conducted using a calibrated weather station while the solar irradiance was measured using a computer-based pyranometer software between 9:00 am and 6:00 pm on February 15, 2026. Data of solar irradiance and the atmospheric parameters (atmospheric temperature and pressure) were simultaneously measured. Data collection covered one full day under clear sky conditions to capture daytime variations of both the irradiance and the atmospheric components studied in this work. The collected data were organised into tables and graphs to illustrate trends and patterns. Correlation analysis was performed to determine the relationship between solar irradiance and atmospheric parameters. Graphical representations of temperature, pressure, and solar irradiance were used to examine the interdependence or relationship between the variables, while correlation coefficients quantified the strength and direction of linear relationships between the variables.

3.0 Results and discussion

Table 1.0 shows the hourly data of atmospheric temperature, atmospheric pressure, and solar irradiance of Idah, measured between 9:00 am and 6:00 pm on February 15, 2026, at Mathson Schools, Idah, Kogi State, Nigeria. It was observed that the atmospheric temperature shows a gradual increase from morning to late afternoon, followed by a slight decline toward evening. At 9:00 am and 10:00 am, the temperature remained constant at 28°C, which shows a relatively cool morning period when solar heating of the Earth's surface is still limited. As the day progressed, temperature increased steadily, reaching 29°C at 11:00 am and 12:00 pm. Between 1:00 pm and 3:00 pm, temperature increased more sharply from 31°C to 35°C, indicating peak surface heating during the early afternoon, with the maximum temperature of 36°C been recorded at 5:00 pm. This is consistent with the thermal lag effect, where the highest air temperature occurs after peak solar radiation as a result of the time required for the Earth's surface and lower atmosphere to absorb the heat and re-emit it. The results also showed a slight decrease to 35°C at 6:00 pm which indicates the onset of evening cooling as incoming solar radiation diminished. In the case of atmospheric pressure, the atmospheric pressure showed a gradual decreasing trend from morning to afternoon, followed by minor fluctuations in the evening. At 9:00 am, 10:00 am, and 11:00 am, the pressure remained relatively stable at 1013 hPa, which suggests a minimal atmospheric disturbance during the morning hours. As day progressed, pressure decreased slightly to 1012 hPa at 12:00 pm and further to 1011 hPa at 1:00 pm, while the pressure of 1006 hPa being the lowest was observed at 5:00 pm. This coincides with the highest recorded temperature, and this inverse relationship between temperature and pressure is because, as air warms, it expands, becomes less dense, and which results in the decrease of surface pressure.

In the same way, there were variations in the solar irradiance too just like in the atmospheric pressure and temperature. Solar irradiance values were relatively low (407.2 W/m² and 409 W/m² respectively), between 9:00 am and 10:00 am, when the temperature was low, or probably due to longer atmospheric path length from the sun, which increases scattering and absorption of solar radiation, but increased at 11:00 am and 12:00 pm to 609.5 W/m² and 689.6 W/m² respectively. Peak solar irradiance of 918.4 W/m² occurred at 2:00 pm, indicating the period of maximum solar energy availability at the study location, Idah, Kogi state, which aligns with near-overhead sun conditions and minimal shading effects as well as higher temperature in the area. After 2:00 pm, a gradual decline of solar irradiance to 854.6 W/m² at 3:00 pm and 735.7 W/m² at 4:00 pm was observed. A sharp drop of 357.1 W/m² and 116.8 W/m² was observed at 5:00 pm and 6:00 pm in that order as the sun approached the horizon and solar input significantly diminished. The results demonstrate a strong positive relationship between solar irradiance and atmospheric temperature throughout the day, such that the periods of increasing solar irradiance corresponded to rising temperatures, particularly between 10:00 am and 3:00 pm, while in with the atmospheric pressure, atmospheric pressure showed an inverse relationship with solar irradiance. As pressure decreases, solar irradiance increased, and as such, the lowest pressure values coincided with the near-peak solar radiation periods. The observed patterns indicate that atmospheric temperature and pressure significantly influence the availability and distribution of global solar radiation in Idah. High solar irradiance during midday hours suggests strong potential for solar energy applications in the area, particularly between 11:00 am and 3:00 pm.

Table 1.0: Hourly atmospheric temperature, pressure and solar irradiance

Time	Temperature (°C)	Pressure (hPa)	Solar irradiance (W/m²)
9:00 AM	28	1013	407.2
10:00 AM	28	1013	409
11:00 AM	29	1013	609.5
12:00 PM	29	1012	689.6
1:00 PM	31	1011	736.4
2:00 PM	34	1008	918.4
3:00 PM	35	1007	854.6
4:00 PM	35	1007	735.7
5:00 PM	36	1006	357.1
6:00 PM	35	1007	116.8

Figure 1.0 represents the graphical relationship between hourly atmospheric temperature and global solar irradiance measured over the daytime period. In the morning hours (9:00 am–10:00 am), solar irradiance values are relatively low, and atmospheric temperature remains stable at a lower level. This behavior is expected due to the low solar elevation angle during early hours, which causes solar radiation to pass through a longer atmospheric path. As a result, a significant portion of the incoming radiation is scattered or absorbed before reaching the Earth's surface, limiting surface heating and keeping atmospheric temperatures moderate. As the day advances toward late morning and early afternoon (11:00 am–2:00 pm), the figure shows a pronounced increase in solar irradiance, reaching a maximum during this period. This rise corresponds to the sun's higher position in the sky, which allows more direct and intense solar radiation to reach the surface. Atmospheric temperature increases concurrently, indicating a strong positive relationship between solar irradiance and temperature. After the peak solar irradiance period, typically observed in the early afternoon, the figure reveals a gradual decline in solar irradiance as the sun begins to descend. However, atmospheric temperature does not immediately decrease at the same rate. but remains high or continues to increase slightly before eventually declining.

Between 5:00 pm–6:00 pm, both solar irradiance and atmospheric temperature show a clear downward trend, in which the sharp reduction in solar irradiance reflects reduced incoming solar energy due to the low solar angle, while the decline in temperature indicates the dominance of cooling processes such as longwave radiation loss and reduced surface heating.

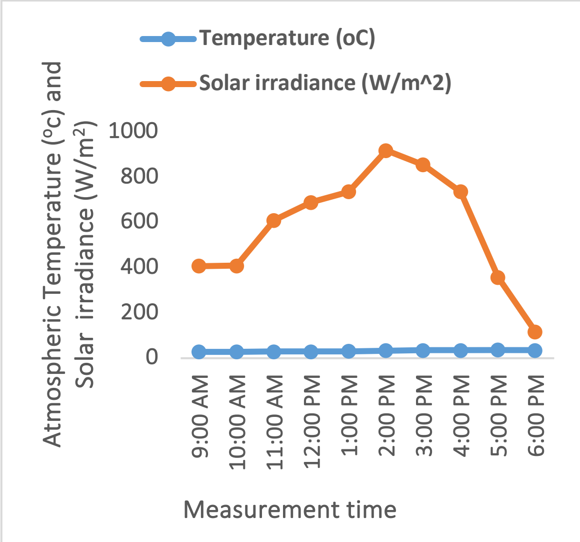


Fig. 1.0: Graphical representation of hourly atmospheric temperature and solar irradiance over the given time.

Figure 2.0 illustrates the relationship between hourly atmospheric pressure and global solar irradiance over the given time period. The results show that during the morning hours (9:00 am–10:00 am), solar irradiance is relatively low, and atmospheric pressure remains high and nearly constant. As the day progresses toward midday (11:00 am–2:00 pm), the figure shows a significant increase in solar irradiance, reaching peak values during the early afternoon, while the atmospheric pressure exhibits a gradual decrease. After the peak irradiance period, solar irradiance begins to decline as the sun's elevation angle decreases, while the atmospheric pressure gradually stabilises toward the evening hours.

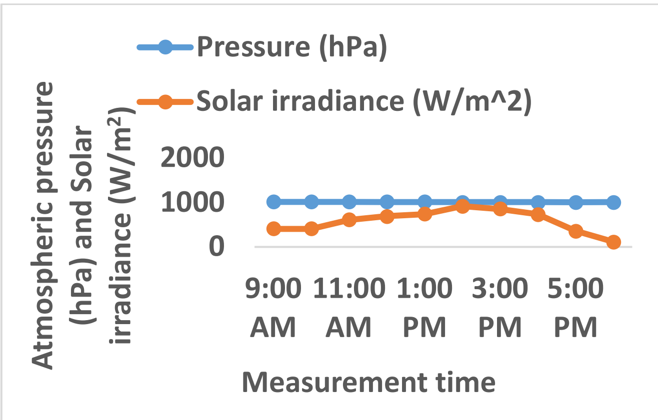


Fig. 2.0: Graphical representation of hourly atmospheric pressure and solar irradiance over the given time.

Table 2.0 presents the results of the correlation analysis between global solar irradiance and the two atmospheric parameters: atmospheric temperature and atmospheric pressure. The correlation coefficients quantify the strength and direction of the linear relationship between solar irradiance and each variable. The correlation coefficient between solar irradiance and atmospheric temperature is 0.065 (6.5%), which shows a week positive relationship. This suggests that slight increase in atmospheric temperature will result in an increase in solar irradiance; however, the relationship is not strong. In contrast, the correlation coefficient between atmospheric pressure and solar irradiance is – 0.036 (3.6%), which indicates a very weak negative relationship. This inverse relationship implies that as atmospheric pressure tends to decrease slightly, solar irradiance increases.

Table 2.0: Results of correlation analysis of solar irradiance with atmospheric temperature and atmospheric pressure

Correlation coefficient	Solar irradiance
Temperature	0.065
Pressure	-0.036

4.0 Conclusion

The result of this study revealed that solar irradiance exhibits a pronounced diurnal cycle, increasing from morning to early afternoon and declining toward evening period. Atmospheric temperature and solar irradiance followed the same trends, while atmospheric pressure showed an inverse relationship with solar irradiance, as solar irradiance increased with decrease in atmospheric pressure, although the effect was weak. The correlation analysis confirmed that temperature and pressure have influence on solar irradiance in the area, though limited linear correlation as the correlation coefficient between the solar irradiance and the atmospheric pressure was -0.036 (-3.6%) while which is negative relationship the correlation coefficient with the atmospheric temperature was 0.065 (6.5%) which is positive relationship.

These findings demonstrate that atmospheric conditions have influence on solar irradiance and this provide insight into local solar energy potential in the study area, Idah or Kogi State as a whole. In addition, the results provide an insight regarding the period of time in which higher solar energy is expected in this research area, Idah, Kogi state. It can be concluded that though, the correlation coefficients between the solar irradiance with the atmospheric temperature and pressure are low, there exists a relationship between solar irradiance and the two atmospheric parameters considered in this work. This study is valuable as it will inform solar energy forecasting, optimize solar panel placement, and enhance energy output predictions, supporting effective deployment of solar energy systems in the region.

5.0 Recommendation

It is recommended that solar energy systems in Idah be designed to utilise peak solar irradiance periods between 11:00 am and 3:00 pm. It is also recommended that data of many days or months be used for the similar work in future. Additionally, continuous monitoring of atmospheric parameters should be implemented for improved solar energy planning.

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