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Longwave Radiation Over Jazan, the Kingdom of Saudi Arabia

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Abstract: ***This study examines the monthly variation of downward longwave radiation (DLR) over Jazan, Saudi Arabia, during 2001-2025. The analysis considers seasonal radiation patterns and their relationships with cloud cover, relative humidity, air temperature, and atmospheric pressure. The reported annual mean DLR was 419.55 W/m². Monthly values ranged from 396.67 W/m² in January to 447.91 W/m² in August, representing a seasonal difference of 51.24 W/m². Polynomial regression analysis indicated relationships between DLR and the selected meteorological parameters. The reported coefficients of determination were 0.885 for cloud cover, 0.762 for relative humidity, 0.784 for air temperature, and 0.994 for atmospheric pressure. These findings describe seasonal radiation variability over Jazan and may support further investigations of atmospheric energy exchange. Statistical relationships should be interpreted cautiously because the meteorological variables may share common seasonal patterns.***

Keywords: Downward Longwave Radiation, Jazan, Meteorological Parameters, Seasonal Variation, Polynomial Regression

1. Introduction

Downward longwave thermal irradiance (DLR) is the thermal infrared energy emitted by atmospheric gases and clouds toward Earth's surface. It is a major component of the surface energy balance, together with incoming solar radiation, outgoing terrestrial radiation, and sensible and latent heat exchanges. By partially offsetting the longwave energy emitted by the surface, DLR influences surface thermal conditions and energy exchange between the land and atmosphere. Its contribution continues throughout the day and night and is particularly important for understanding nighttime radiative cooling, when solar energy is absent, (NASA, 2025).

The magnitude of DLR depends strongly on atmospheric temperature and moisture conditions. Atmospheric temperature influences the intensity of thermal emission, while water vapor affects the atmosphere's capacity to absorb and emit infrared radiation. Consequently, variations in temperature and water-vapor content can produce substantial changes in the longwave energy received at the surface. These physical relationships provide the basis for estimating clear-sky DLR from near-surface meteorological measurements, particularly air temperature and water-vapor pressure. However, their relationships with DLR must be evaluated under the climatic conditions of the location being investigated, (Shanshan Yu, 2018).

Clouds introduce additional variability into atmospheric longwave emission. Their influence depends not only on cloud cover but also on properties such as cloud-base temperature and infrared emissivity. Although clouds can reduce the shortwave solar radiation reaching the surface, they generally increase downward longwave radiation compared with otherwise similar clear-sky conditions. Therefore, the seasonal behavior of DLR cannot be interpreted from temperature alone; changes in cloud characteristics and atmospheric moisture must also be considered. This interaction makes DLR a useful variable for investigating the combined radiative effects of different atmospheric conditions, (M. Nazrul Islam, 2025).

A local assessment is especially relevant for Jazan, also known as Jazan, on the Red Sea coast of southwestern Saudi Arabia. Research based on observations from the Jazan meteorological station has documented pronounced rainfall seasonality and changes in the timing of peak rainfall between earlier and more recent decades. These findings highlight the importance of examining local climatic conditions at monthly rather than exclusively annual scales. They also motivate an investigation of how the seasonal distribution of DLR corresponds to variations in temperature, atmospheric moisture, cloud cover, and precipitation in the study area, (Hi Ku Cho, 2008).

By combining monthly characterization with correlation analysis, this study aims to provide a clearer description of atmospheric longwave energy input over Jazan. The resulting assessment is intended to establish a local baseline for subsequent investigations of surface energy exchange and the meteorological conditions associated with seasonal DLR variability.

2. Results and Discussion

2.1 Monthly averaged values of DLR

The results demonstrate a clear and progressive seasonal variation in downward longwave thermal irradiance throughout the year. The data indicate an overall annual mean of 419.55 W/m². The lowest thermal irradiance occurs during the winter months, with a minimum of 396.67 W/m² in January. As atmospheric temperatures and humidity increase, the irradiance exhibits a continuous upward trend, peaking at a maximum of 447.91 W/m² in August. This robust monthly distribution highlights the strong correlation between seasonal atmospheric dynamics and the amount of thermal energy returned to the Earth's surface as shown in Fig.1

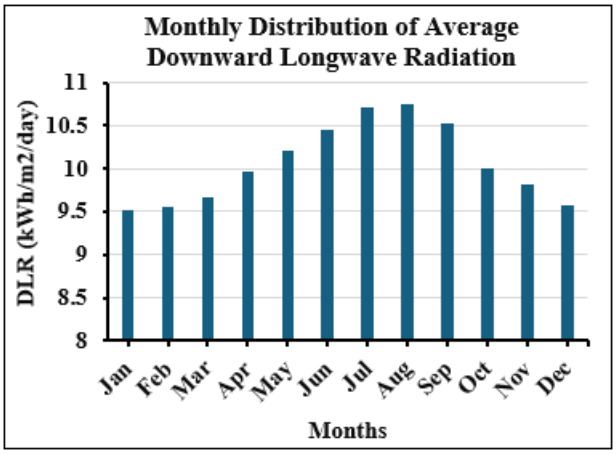


Figure 1: Monthly Distribution of Average Downward Longwave Radiation

Figure 2 represents the monthly average values of some metrological parameters, cloud cover, ambient temperature, Relative humidity and atmospheric pressure.

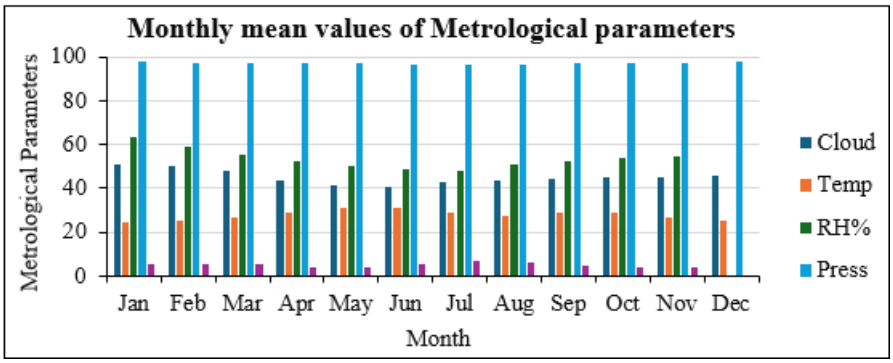


Figure 2: Monthly Mean Average values of meteorological parameters.

2.2 Statistical Error Estimation

The relationships between DLR and meteorological parameters are examined. They describe physical expectations rather than confirmed results from your dataset.

1) **Cloud cover:** Increased cloud cover generally enhances DLR because clouds emit thermal infrared radiation toward the surface. However, the magnitude of this enhancement depends on cloud properties, particularly cloud-based temperature, height, and infrared emissivity, (A. Viúdez-Mora, 2014).
2) **Air temperature:** A positive correlation between air temperature and DLR is generally expected because warmer atmospheric layers emit more thermal infrared radiation. Consequently, higher DLR during warmer months may partly reflect the seasonal increase in atmospheric temperature, (Kaicun Wang, 2009).
3) **Relative humidity:** At comparable air temperatures, higher relative humidity indicates greater water-vapor content, which can enhance atmospheric longwave emission toward the surface. However, because relative humidity also depends on temperature, its monthly correlation with DLR is not necessarily positive and should be interpreted alongside temperature and other moisture indicators, (D. M. Murphy, 2005).
4) **Atmospheric pressure:** May influence DLR through pressure-dependent infrared absorption and associated changes in meteorological conditions. A negative correlation, if observed, may reflect lower-pressure periods coinciding with warmer, moister, or cloudier conditions that enhance atmospheric longwave emission, rather than a direct negative effect of pressure." This is a possible interpretation, (J. Shakespeare, 2021).

The coefficient of determination (R^2) is calculated using:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (1)$$

where:

- y_i: observed DLR value,
- $\hat{y}_i$: DLR value predicted by the regression model.
- $\bar{y}$: mean of the observed DLR values.
- n: number of observations.

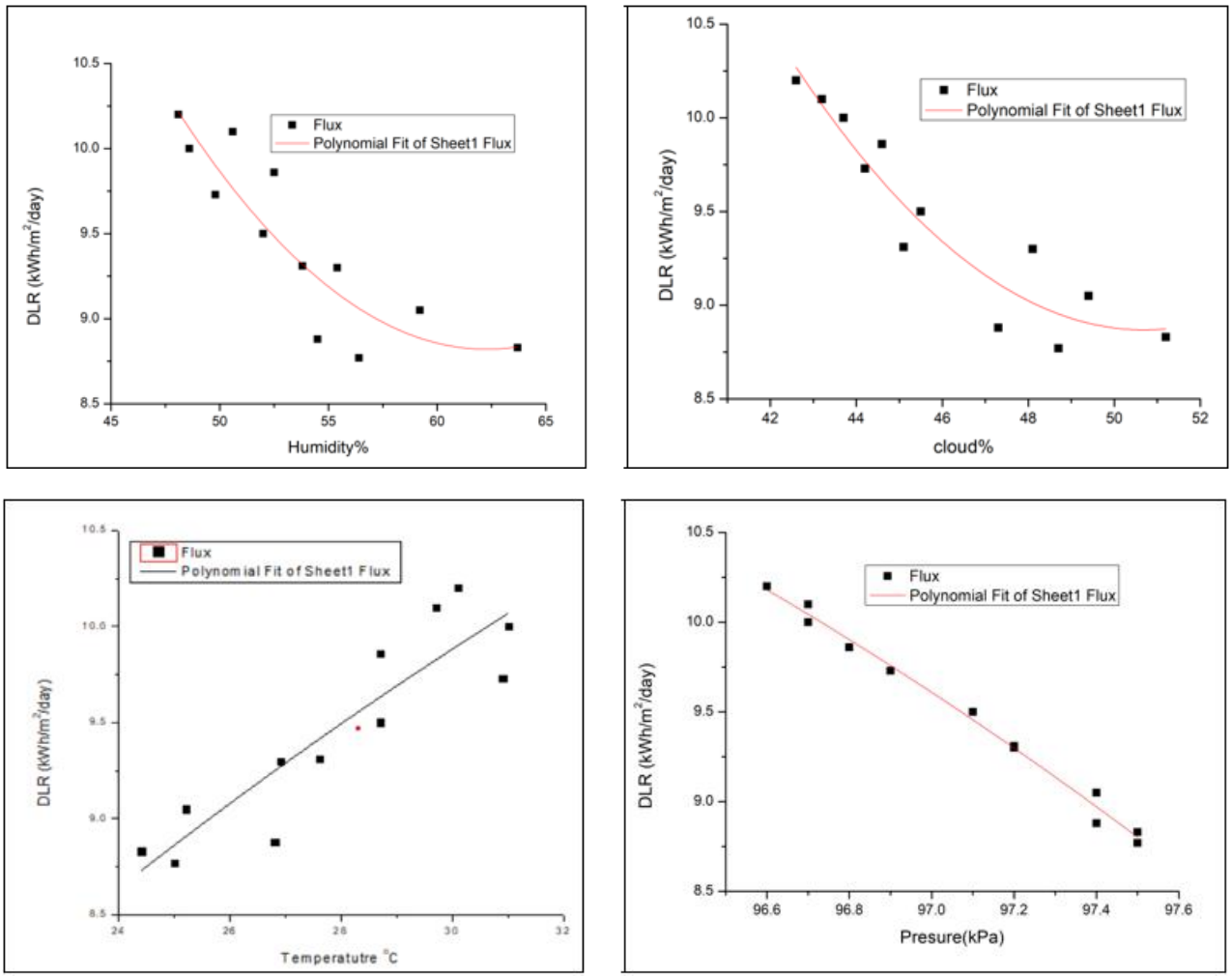


Figure 3: Correlation between DLR against the metrological parameters.

Table 1: Parameters for the correlation 0f DLR and the metrological parameters.

Relation	Regression equations	R2
DLR&CL%	DLR = 63.8 -2.16 CL + 0.02 CL2 2.553 D +2.348	0.885
DLR &Humidity%	DLR = 35.72 - 0.86 H =0.007 H2	0.762
DLR &Temperature	DLR = 1.31+0.38 T- 0.00327 T2	0.784
DLR &Pressure	DLR = -1770 + 38.2 P - 0.21 P2	0.994

The following discussion is based on four curves and four polynomial regression equations and coefficients of determination R^2. The analysis investigates the relationships between downward longwave radiation (DLR) and four meteorological parameters: cloud cover, relative humidity, air temperature, and atmospheric pressure. DLR is expressed in kWh/m²/day, while the meteorological parameters are expressed in their respective units.

The analysis of the relationship between downward longwave radiation and meteorological parameters in Jazan reveals that atmospheric conditions play an important role in explaining the variability of downward longwave radiation. The results demonstrate nonlinear relationships between DLR and cloud cover, relative humidity, air temperature, and atmospheric pressure.

The graphical analysis shows a decreasing trend in DLR with increasing relative humidity, atmospheric pressure and cloud cover over the investigated ranges. The corresponding polynomial regression models demonstrate reasonably good statistical performance, with coefficients of determination of 0.762, 0.994 and 0.885, respectively.

The temperature regression model exhibits a coefficient of determination of 0.784, indicating a relatively strong association between atmospheric temperature and downward longwave radiation. This relationship is consistent with the fundamental role of atmospheric temperature in determining longwave radiative emission.

Among the four investigated parameters, atmospheric **pressure** exhibits the highest R^2 value of (0.994), suggesting an exceptionally strong statistical association with DLR in the analyzed dataset. Cloud cover also demonstrates a relatively strong relationship, with an R^2 value of 0.885. These findings suggest that meteorological parameters can be useful predictors of downward longwave radiation in Jazan. However, relationships should be interpreted in the context of interactions among atmospheric variables rather than as evidence of direct causation.

Overall, the results emphasize the importance of meteorological conditions in understanding the seasonal and atmospheric variability of downward longwave radiation.

Such relationships can be useful in developing empirical models for estimating DLR and evaluating atmospheric radiative contributions to surface energy balance and building thermal performance in the hot climate of Jazan.

3. Conclusion

This study examined the monthly distribution of downward longwave radiation over Jazan, Saudi Arabia, during 2001-2025. The reported annual mean was 419.55 W/m², with monthly values ranging from 396.67 W/m² in January to 447.91 W/m² in August. The seasonal variation indicates changes in atmospheric longwave energy received at the surface throughout the year. Polynomial regression analysis identified relationships between DLR and cloud cover, relative humidity, air temperature, and atmospheric pressure. Atmospheric pressure showed the highest reported coefficient of determination ($R^2 = 0.994$), followed by cloud cover ($R^2 = 0.885$), air temperature ($R^2 = 0.784$), and relative humidity ($R^2 = 0.762$). These associations should not be interpreted as direct causal relationships because the meteorological variables may be influenced by common seasonal conditions. The findings provide a regional basis for further investigation of atmospheric radiation and surface energy exchange in Jazan.

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