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Wavelet-Based Analysis of Temperature and Relative Humidity: A Case Study from Khepupara, Patuakhali, Bangladesh (2019)

Md Shah Alam[1]*

[1] Bangladesh Meteorological Department.

*Autor para correspondencia: Md Shah Alam, Nirbindu94@gmail.com

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Abstract

Temperature and relative humidity (RH) are two critical meteorological variables that shape weather patterns, human comfort, and climate processes. While conventional correlation techniques provide only a static relationship, wavelet analysis enables exploration of time–frequency interactions, revealing how correlations evolve across different scales. In this study, daily temperature and RH data for 2019 analyzed using statistical methods and wavelet coherence. Results show that temperature range between 14–35°C with a mean of 27.29°C, while RH varies between 21–100 % with a mean of 82.39 %. The overall relationship between temperature and RH is negative, with strong inverse coherence observed during the pre-monsoon summer and weaker coupling during the monsoon. The findings highlight the advantages of wavelet analysis in revealing non-stationary, scale-dependent interactions between climate variables.

Keywords: *Wavelet-Based Analysis,Relative Humidity.*

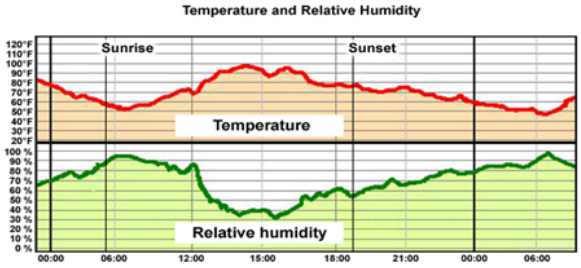
Resumen

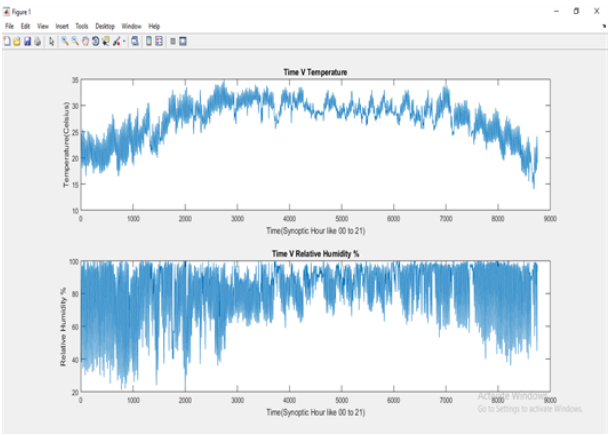
*La temperatura y la humedad relativa (HR) son dos variables meteorológicas críticas que determinan los patrones meteorológicos, el confort humano y los procesos climáticos. Si bien las técnicas de correlación convencionales ofrecen únicamente una relación estática, el análisis de ondículas (*wavelets*) permite explorar las interacciones tiempo-frecuencia, revelando cómo evolucionan las correlaciones a distintas escalas. En este estudio se analizaron datos diarios de temperatura y HR correspondientes a 2019 mediante métodos estadísticos y coherencia de ondículas. Los resultados muestran que la temperatura oscila entre 14 y 35 °C, con una media de 27,29 °C, mientras que la HR varía entre el 21 % y el 100 %, con una media del 82,39 %. La relación general entre la temperatura y la HR es negativa; se observa una fuerte coherencia inversa durante el verano previo al monzón y un acoplamiento más débil durante el monzón. Los hallazgos destacan las ventajas del análisis de ondículas para revelar interacciones no estacionarias y dependientes de la escala entre las variables climáticas.*

Palabras claves: *Análisis basado en ondículas, humedad relativa.*

1. Introduction

Relative humidity (RH) and temperature are fundamental parameters in atmospheric science. Their interaction influences weather dynamics, cloud formation, precipitation, and thermal comfort. In tropical and monsoon-dominated climates, such as South Asia, their relationship is especially important because it varies significantly across seasons. Traditionally, statistical approaches such as Pearson's correlation or regression models have been used to quantify the link between RH and temperature. However, these methods assume stationarity, which limits their ability to capture seasonal and scale-dependent variability. Wavelet analysis, in contrast, is a powerful time–frequency technique that enables the detection of localized correlations across multiple temporal scales. The aim of this study is to investigate the correlation between RH and temperature for the year 2019 using both descriptive statistics and wavelet coherence analysis. By doing so, the research provides a more nuanced understanding of their interaction over seasonal cycles.





2. Methodology

2.1. Data Collection

- Daily average temperature (°C) and relative humidity (%) for the year 2019 are used.
- The dataset consisted of 365 values for each parameter.

2.2. Statistical Analysis

Descriptive statistics (mean, median, maximum, minimum, standard deviation, range, and norms) are calculated to summarize the variation of temperature and RH.

2.3. Wavelet Analysis

- The Continuous Wavelet Transform (CWT) is applied to both series using the Morlet wavelet.
- Wavelet Power Spectrum (WPS): Used to identify dominant time–frequency components of temperature and RH.
- Wavelet Coherence (WTC): Applied to explore localized correlation between RH and temperature in the time–frequency domain.
- Cone of influence and significance levels (95 %) are applied following Torrence and Compo (1998).

3. Results

3.1. Temperature Statistic

The statistical summary of temperature is presented in Table 1. The maximum temperature was 35°C, while the minimum was 14°C, giving a range of 21°C. The mean was 27.29°C, close to the median value (28.5°C), with a standard deviation of 3.86°C, indicating moderate variability.

Tabla 1: Statistical summary of Temperature (°C) for 2019.

Parameter	Unit	Parameter	Unit
Maximum	35	Standard Dev	3.86
Minimum	14	Median Abs Dev	2
Range	21	Mean Abs Dev	3.101
	27.29	L1 Norm	7.969e+4
Median	28.5	L2 norm	1489
Mean Abs	29.75	Max Norm	35

3.2. Wavelet Analysis

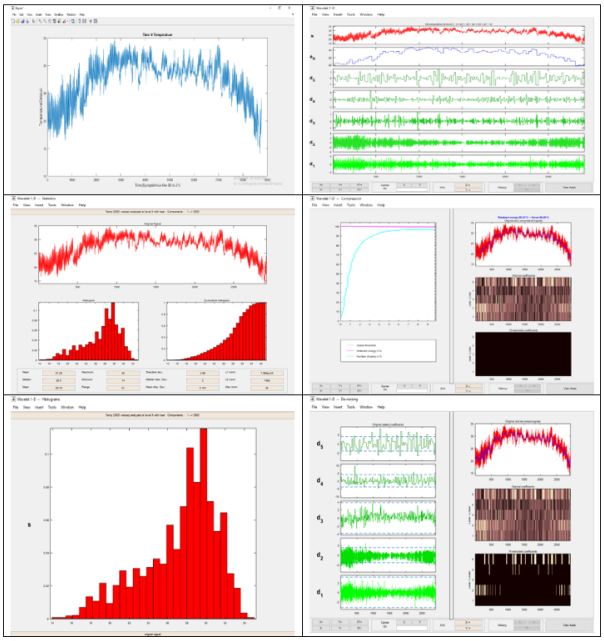


Figura 1: Wavelet Analysis

The statistical summary of RH is presented in Table 2. The maximum RH was 100 %, while the minimum was 21 %, producing a range of 79 %. The mean RH was 82.39 %, with a standard deviation of 16.7 %, reflecting substantial seasonal variation.

3.3. Relative Humidity Statistics

Tabla 2: Statistical summary of Relative Humidity (%) for 2019.

Parameter	Unit	Parameter	Unit
Maximum	100	Standard Dev	16.7
Minimum	21	Median Abs Dev	9
Range	79	Mean Abs Dev	13.36
	82.39	L1 Norm	2.406e+5
Median	88	L2 norm	4543
Mean Abs	96.05	Max Norm	100

3.4. Wavelet Analysis

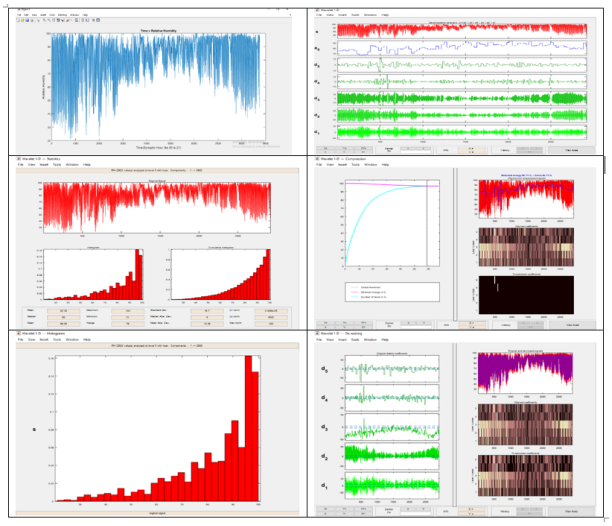


Figura 2: Wavelet Analysis

3.5. Wavelet Analysis Results

• Temperature Power Spectrum: Strong power concentrated at seasonal scales (90–120 days) and short-term (20–30 days) oscillations.
• RH Power Spectrum: High power during the monsoon (90–120 days), reflecting seasonal rainfall-driven variability.

• Wavelet Coherence (WTC):

o Pre-Monsoon (March–May): Strong negative coherence at intra-seasonal scales (15–30 days).
o Monsoon (June–September): Weaker coherence, with intermittent positive patches caused by rainfall events.
o Winter (December–February): Low coherence, with stable atmospheric conditions and minimal fluctuations.

4. Discussion

The descriptive statistics highlight the contrasting behavior of temperature and RH across the year. High temperatures in the pre-monsoon season coincide with lower RH, while monsoon rainfall increases RH, reducing temperature variability. The wavelet analysis reveals that the temperature–RH relationship is non-stationery and scale-dependent. The strong negative coherence during summer supports the thermodynamic principle that higher temperatures reduce RH when moisture input remains limited. Conversely, the weakened coherence during the monsoon reflects the influence of rainfall, which decouples the direct temperature–humidity relationship. In winter, stable dry conditions explain the low coherence observed.

This confirms that while a simple correlation captures the broad negative relationship, wavelet methods uncover the dynamic, time–frequency-dependent interaction between RH and temperature. Such insights are crucial for understanding seasonal climate variability and for improving models of weather prediction and climate studies.

5. Conclusion

This study examined the correlation between temperature and relative humidity (RH) in 2019 using statistical summaries and wavelet coherence analysis. The results indicate that:

1. Temperature ranged from 14–35°C, while RH varied between 21–100 %, highlighting strong seasonal variability.

2. The overall correlation between RH and temperature was negative, consistent with physical expectations.

3. Wavelet analysis revealed that the correlation is not constant but varies across seasons and time scales.

o Strong negative coherence was observed in summer.
o Coherence weakened during the monsoon due to rainfall influence.
o Winter exhibited low coherence with stable conditions.

The findings demonstrate the advantage of wavelet analysis in capturing time–frequency-dependent relationships between climate variables, which cannot be revealed through traditional correlation methods. Future work should apply multi-year datasets and include additional meteorological parameters to assess long-term variability and climate change impacts

6. References

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