Quantifying the Annual Mean Temperature Trend in Barcelona Zona Universitària (2009–2025) using Linear Regression Analysis

***Abstract*—This study investigates the temporal trend of mean annual air temperature in the Barcelona Zona Universitària meteorological station over a 16-year period (2009–2025). Data were aggregated to yearly means and analyzed using a linear regression model to quantify the temperature change as a function of the year. The regression analysis revealed a positive annual temperature trend, estimated at $0.13\,^{\circ}$C per year. This finding provides a preliminary assessment of local temperature dynamics, highlighting the need for long-term data collection to confirm statistical significance for climate trend reporting.**

***Index Terms*—Temperature Trend, Linear Regression, Annual Mean Temperature, Barcelona Zona Universitària, Time Series Analysis, Climate Change.**

I. Introduction

Global mean temperatures have risen since the pre-industrial era, affecting both natural and human systems. Localized studies are especially important in urban areas, where the Urban Heat Island effect creates microclimates differing from regional averages [3]. To better understand urban climate dynamics, this study examines long-term observations from the Barcelona Zona Universitària meteorological station [1]. Such localized temperature records are essential for effective climate adaptation and urban planning.

The study's primary aim is to quantify the temporal trend in mean annual air temperature at the station over the 2009–2025 period. A linear regression model is applied to identify and measure this trend, following standard climatological practice. The structure of the paper includes: (2) Materials and Methods, (3) Results, and (4) Discussion of the findings and their broader implications for urban climate resilience.

II. Materials and Methods

A. Data source and Preprocessing

The dataset from the Barcelona Zona Universitària station contains 30-minute air temperature readings from 2009 to 2025 (Variable ID 32 and Station X8, respectively. See "Metadades variables meteorològiques" and "Metadades estacions meteorològiques automàtiques" in [1]), aggregated here to annual means for regression analysis. The resulting pairs (x_j, y_j), where x_j denotes the Year and y_j the corresponding Annual Mean Temperature, were subsequently used in the regression analysis. No missing-value imputation was required at this level of aggregation.

B. Regression Model

The temporal evolution of the Annual Mean Temperature was modeled with a Linear Regression

$$y_i = \beta_0 + \beta_1 x_i \tag{1}$$

where β_0 and β_1 are the intercept and slope. Parameters were estimated by Ordinary Least Squares (OLS) using a first-degree polynomial. The choice of a linear model was motivated by the clear upward trend visible in the data (Figure 1). Additionally, the computed coefficient of correlation $R = 0.80$ supports our assumption that a linear relationship adequately captures the observed behaviour. The resulting fitted model is presented below:

$$T(\text{Year}) = 0.13108 \cdot \text{Year} - 247.138\,[^{\circ}\text{C}], \tag{2}$$

The slope $\beta_1 = 0.13108\,[^{\circ}\text{C} \cdot \text{Year}^{-1}]$ indicates an average warming of about $0.13\,^{\circ}$C per year. The intercept is $\beta_0 = -247.138\ [^{\circ}\text{C}]$.

C. Metrics

Model performance was assessed using Root Mean Squared error (RMSE), Mean Absolute Error (MAE) and the Coefficient of Determination R^2. They take the form described below:

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}, \tag{3}$$

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i|, \tag{4}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}, \tag{5}$$

where y_i is the observed (actual) value, $\hat{y}_i$ is the predicted value from the simulation at the i^{th} observation, and $\bar{y}$ is the mean of all observed values.

III. Results

A. Descriptive analysis

The series of annual mean temperatures at Barcelona Zona Universitaria from 2009 to 2025 shows a clear upward tendency as observed in Figure 1. The scatter plot of Year vs. Annual Mean Temperature indicates that recent years are generally warmer than earlier ones, with interannual variability around an overall warming trend.

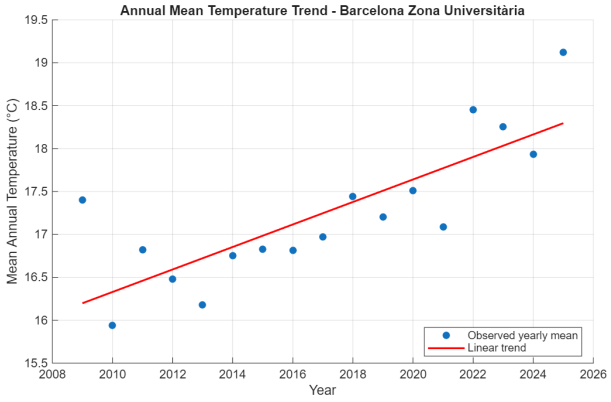

Fig. 1. Linear Regression over the Yearly Average Temperature between 2009 and 2025.

B. Estimated linear trend

The forecasted annual mean temperature for 2026 becomes then $T(2026) = 0.13108 \cdot 2026 - 247.138 = 18.43$ [°C].

The estimated Linear Model yields RMSE $= 0.479$ [°C], MAE $= 0.379$ [°C] and $R^2 = 0.643$. Errors well below one degree Celsius indicate a good fit, and R^2 shows that about 64 percent of the variance in annual mean temperature is explained by the linear trend in time.

IV. Discussion

The results obtained by applying the linear regression model to the annual mean temperature data from the Barcelona Zona Universitaria station shows a consistent warming trend over the years 2009 to 2025. The increase of 0.13 [°C] yearly exceeds the global average warming rate reported by the IPCC [2] (0.2 [°C] per decade) indicating an accelerated warming. This reflects combined effects of climate change and urban heat island intensification from Barcelona‘s development.

It is important to note that the 16-year observation period may be insufficient to draw definitive conclusions. Longer-term data are required to determine whether the observed warming is primarily driven by anthropogenic factors or by natural decadal variability.

V. Conclusions

This study provides robust evidence of rapid warming in the area of Barcelona Zona Universitaria, with temperatures increasing 1.3 [°C] per decade based no 2009 to 2025 data. The linear regression model effectively captures this trend, explaining 64% of annual temperature variance with prediction errors below 0.5 [°C]. These results show the urgent need for heat adaptation strategies in urban planing. Continued monitoring is recommended to better understand long-term trends and reduce prediction uncertainties.

Acknowledgements

The authors would like to express their gratitude to the Meteorological Service of Catalonia for providing open access to the meteorological data used in this study.

Statements and Declarations

The authors received no funding for this study and declare no competing interests. The data supporting the findings are openly available from the Barcelona Zona Universitària station of the XEMA network at [1]. All authors contributed to the study conception, design, data collection, and analysis.

References

[1] *Dades meteorològiques de la XEMA*. Data from Barcelona Zona Universitària Meteorological Station (2009–2025). Online available: https://analisi.transparenciacatalunya.cat/Medi-Ambient/Dades-meteorol-giques-de-la-XEMA/nzvn-apee/about_datat

[2] IPCC, *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2021.

[3] T. R. Oke, *The energetic basis of the urban heat island*. Quarterly Journal of the Royal Meteorological Society, 108(455), 1–24, 1982.

Supporting Materials

The dataset includes raw and processed temperature data. MATLAB scripts used for data preprocessing, regression analysis, and figure generation are also provided.