

Analysis Daily Maximum Temperature Prediction in East Java Under the RCP 8.5 Scenario

Uston Nawawi Christanto¹ and Brina Miftahurrohmah²

^{1,2}Department Information System, Universitas Internasional Semen Indonesia, Gresik, Indonesia

*Corresponding author: uston.christanto21@student.uisi.ac.id

ABSTRACT

East Java, a province of critical economic and agricultural importance in Indonesia, faces escalating risks from climate change. This study provides high-resolution projections of daily maximum temperatures for the period 2025–2050 to establish an evidence-based foundation for regional adaptation strategies. Using a Support Vector Regression (SVR) model, this study projects future temperature dynamics under the high-emission Representative Concentration Pathway 8.5 (RCP 8.5) scenario. The results reveal a statistically significant long-term warming trend of $+0.03^{\circ}\text{C}$ per year. Spatially, the model identifies two distinct risk patterns: (1) persistent absolute heat "hotspots" in northwestern urban lowlands ($>32^{\circ}\text{C}$), driven by the Urban Heat Island (UHI) effect; and (2) the most rapid warming anomalies (up to $+0.45^{\circ}\text{C}$) in southern and coastal agricultural regions. A crucial finding is a projected seasonal shift where the wet season is expected to become systematically hotter than the dry season, introducing new humidity-compounded heat stress. These differentiated risks underscore the urgent need for targeted, data-driven policies in agriculture, public health, and urban planning to build climate resilience for East Java's high-emission future.

Keywords: Climate Change, RCP 8.5, Support Vector Regression (SVR), East Java, Temperature Projection.

1. INTRODUCTION

Global warming has now become a critical issue faced by all nations across the world. This phenomenon is reflected in the consistent rise of average temperatures in the Earth's atmosphere, oceans, and land surfaces. A report from the World Meteorological Organization (WMO) notes that the period from 2015 to 2024 represents the hottest decade in the history of instrumental temperature records (World Meteorological Organization, 2024). In fact, 2024 is projected to become the first recorded year in which the global average temperature exceeds the 1.5°C threshold above pre-industrial levels (reference period 1850–1900). The ongoing rise in temperature is not a mere temporary fluctuation but rather a strong indication of a long-term, systemic shift in the global climate — clear evidence that our planet is undergoing a profound and tangible transformation. (World Meteorological Organization, 2024). The Intergovernmental Panel on Climate Change (IPCC) further emphasizes that global warming will continue to intensify and broaden these impacts unless urgent action is taken (World Meteorological Organization, 2024).

The rise in greenhouse gas (GHG) concentrations particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) is a primary driver of global warming (World Meteorological Organization, 2024). These gases possess the ability to trap heat within the Earth's atmosphere, thereby intensifying the greenhouse effect and contributing to sustained warming (UNFCCC, 2024). The consequences of increased greenhouse gas emissions are evident in shifting weather patterns, which pose a direct threat to both global and regional food security. This disruption affects the livelihoods of millions who depend on climate-sensitive

sectors such as agriculture and fisheries, while also leading to widespread ecosystem degradation and significant biodiversity loss (UNFCCC, 2024).

Amid the dynamics of global climate change, tropical regions such as Indonesia including East Java Province are experiencing tangible impacts, particularly in the form of rising extreme temperatures and altered patterns of daily temperature variation. Studies indicate that since 2024, Indonesia has recorded dozens of additional extreme heat days due to global warming. This condition is further exacerbated by the wet bulb effect, in which high humidity impairs the body's ability to cool itself, significantly elevating health risks even when absolute temperatures are not extreme. (Tachev, 2025).

The impacts of extreme heat extend across multiple sectors. In agriculture, elevated temperatures and unpredictable rainfall patterns reduce productivity and heighten the risk of crop failure (Nurhaliza, 2025). In the health sector, rising cases of dehydration, heatstroke, respiratory issues, and mental health disorders have emerged as serious concerns (Tachev, 2025). Meanwhile, in the energy and labor sectors, increasing demand for cooling and declining work productivity further contribute to economic strain (Levin et al., 2022).

East Java, as a region with dense socio-economic and agricultural activity, is highly vulnerable to hydrometeorological disasters such as droughts and floods, whose frequency has steadily increased in recent years (Azmi, 2024; Pratama, 2024). Future projections also point to an alarming trend. Data from the Meteorology, Climatology, and Geophysical Agency (BMKG) and studies by the National Research and Innovation Agency (BRIN) indicate that East Java is facing a wide range of complex climate threats (PRIMA-BRIN, 2025). Therefore, the development of accurate temperature prediction models is crucial as a foundation for formulating integrated and equitable climate mitigation and adaptation strategies (Setyadi Pratikto et al., 2014).

In response to this critical need and amid growing global challenges posed by rising daily maximum temperatures due to climate change accurate predictions at the local scale are essential to support adaptation efforts across vital sectors. Climate projections from global models (Global Climate Models/GCMs), such as those from CMIP5/6 under high-emission scenarios like RCP 8.5, indeed serve as a key reference. However, their coarse spatial resolution limits direct applicability in regional contexts such as East Java Province. Therefore, statistical downscaling approaches are required to ensure that climate projections become more relevant and applicable at the local level.

Various methods have been used in climate prediction, including machine learning algorithms such as Random Forest, Neural Networks, and Support Vector Regression (SVR) (Jamila, 2020; Paniagua-Tineo et al., 2011; Syahreza et al., 2024). SVR is selected due to its proven ability to handle complex nonlinear relationships within multivariate climate data, as well as its demonstrated reliability in numerous previous climate prediction studies (Miftahurrohman et al., 2024). This study is a continuation of previous research that developed and trained an SVR model using regional climate data from East Java, where the SVR model showed higher accuracy and better stability compared to other methods (under review). In this study, the previously trained SVR model is applied to predict daily maximum temperatures

using the latest climate projection data under the Representative Concentration Pathway (RCP) 8.5 scenario, alongside an analysis of potential climate risks in the region.

The RCP 8.5 scenario is chosen because it represents a high greenhouse gas emissions pathway without significant mitigation efforts. This scenario reflects extreme risks and critical adaptation challenges, making it highly relevant to support resilient policy and mitigation planning in vulnerable areas like East Java.

The prediction results will be analyzed to identify potential climate risks and support climate change adaptation planning at the regional level. This study is expected to contribute significantly to the advancement of localized climate prediction models and serve as a valuable reference for policymakers, agricultural stakeholders, and climate adaptation frameworks in East Java.

2. METHODS

This study is categorized as quantitative research employing a predictive approach. Its primary focus is to generate forecasts of daily maximum temperatures across East Java Province for the period 2025 to 2050, by applying a machine learning model developed in previous research. Essentially, this work serves as a continuation of earlier studies, utilizing a pre-trained Extreme Support Vector Regression (SVR) model. The model was originally trained on historical data from 1980 to 2005, derived from two primary sources: the European Centre for Medium-Range Weather Forecasts Reanalysis Fifth Generation (ERA5) and the Beijing Normal University Earth System Model (BNU-ESM), specifically tailored to the Indonesian context. The training phase also incorporated a clustering-based analysis approach.

The selection of SVR as the predictive model in this study is strongly supported by its superior performance in prior experiments.

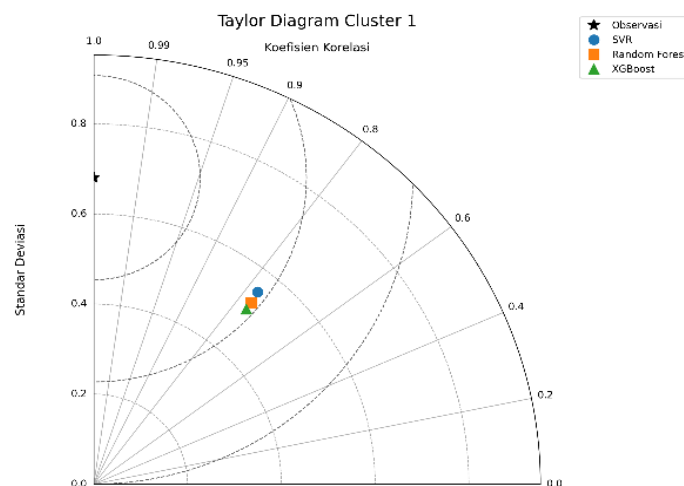


Figure 1. Taylor Diagram

Table 1. Evaluation Model

Model	RMSE	MAPE	MAE
SVR	0.43	1.13	0.34
RF	0.44	1.17	0.35
XGBoost	0.44	1.17	0.35

Based on model evaluation using multiple metrics—including RMSE, MAE, MAPE, correlation, standard deviation, and CRMSE—SVR consistently outperformed both Random Forest (RF) and XGBoost. For instance, SVR achieved the lowest RMSE (0.43), MAE (0.34), and MAPE (1.13), as well as the lowest CRMSE (0.43), indicating higher accuracy and lower prediction error. While all three models shared the same correlation score (0.77), SVR's overall statistical performance confirmed its suitability as the optimal model for forecasting daily maximum temperatures in the regional context.

The primary data used for prediction in this study consists of climate projections based on the Representative Concentration Pathway (RCP) 8.5 scenario, which had been previously downscaled with climate imprint method. RCP 8.5 is one of several greenhouse gas concentration trajectories developed for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) (Ikhwal et al., 2022). It is widely recognized as the high-emission scenario and is often referred to as a "business-as-usual" or pessimistic pathway (Suwarman et al., 2022). The assumptions underlying RCP 8.5 typically involve minimal global climate mitigation efforts, continued dependence on fossil fuels, and high population growth rates, though specific assumptions may vary between Global Climate Models (GCMs) implementing it (Hausfather, 2019). This scenario is projected to result in a radiative forcing level of approximately 8.5 Watts per square meter (W/m^2) by the end of the 21st century, relative to pre-industrial levels (Climate4Life, 2023).

The following section provides a detailed explanation of the methodology applied in this research, encompassing stages such as data preprocessing, model loading, prediction process, analysis of predicted results, discussion, and conclusion. Each of these stages is presented systematically through the following process flow diagram.

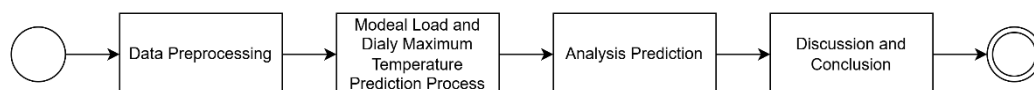


Figure 2. Research Methodology

2.1 Data Preprocessing

The initial stage of this research involved thorough data preprocessing to ensure the quality and reliability of the dataset used for analysis. This phase included the removal of duplicate

entries and missing values, which could otherwise compromise the predictive accuracy and overall performance of the model. Following data cleaning, spatial filtering was conducted based on geographical coordinates to narrow the analysis focus specifically to the East Java region. The selection was made by isolating daily maximum temperature data within the longitude range of 110.7° to 115° East and the latitude range of 9° to 6.5° South. This geographic boundary effectively encompasses the entire main landmass of East Java Province while excluding Bali and smaller islands to the east.

In addition to spatial filtering, the dataset was also temporally constrained to cover the period from January 1, 2025, to December 31, 2050. This time frame was chosen to facilitate medium- to long-term predictive analysis, aligned with climate projections under the Representative Concentration Pathway (RCP) 8.5 scenario. Such spatial and temporal data preparation is a well-established practice in climate modeling studies and is commonly applied in previous research involving climate model projections across Indonesia.

1.1 Support Vector Regression (SVR) Model Loading and Prediction Process

After processing the RCP 8.5 projection data, the next step is to utilize the previously developed SVR model to predict daily maximum temperatures. This ready-to-use model is saved in a file named `best_svr.joblib` and loaded into the analysis environment using Python libraries such as `joblib` or `pickle`.

Once the model is successfully loaded, the cleaned projection data is fed into the model as input. The SVR algorithm then generates predictions based on the decision-tree structures formed during the prior model development. The model produces estimates of daily maximum temperatures for every combination of predictor variables across all grid locations during the 2025–2050 period. The prediction results are saved in appropriate data formats like CSV for further analysis.

1.2 Analysis Prediction

After successfully generating projections of daily maximum temperature in East Java under the RCP 8.5 high-emissions scenario, the next crucial step involved conducting an in-depth and multifaceted data analysis to identify spatial-temporal patterns, quantify warming trends, and assess the broader implications of future temperature increases across the region. The analysis began with a spatial approach, where the predicted data were mapped thematically to identify districts and cities with the highest average temperatures throughout the observation period. This mapping serves to highlight areas potentially exposed to greater thermal stress, which could have direct consequences for agriculture, public health, and water availability.

Beyond geographic distribution, the study examined long-term trends by calculating the average annual temperature increase (expressed in °C/year) over the 2025–2050 period. This trend analysis helps determine the rate of warming in each area and detect consistent year-to-year increases. To enrich the understanding of climate dynamics, seasonal analysis was also conducted to compare temperature patterns between the wet and dry seasons. This comparison offers insights into how climate change may disrupt seasonal cycles and the potential implications for food security and natural resource management.

Furthermore, anomaly analysis was performed to detect regions experiencing the most extreme rates of warming. This was achieved by comparing average temperatures between an early period (2025–2035) and a late period (2041–2050), providing a mid- to long-term perspective on temperature change (Matsinos, 2023). The results were visualized in the form of spatial maps to highlight emerging “hotspots”—areas undergoing the most significant acceleration in warming across East Java.

Overall, such an integrated approach—combining spatial mapping, annual trend analysis, seasonal variation, and anomaly identification—provides an in-depth insight into daily maximum temperature's future dynamics. Such information is invaluable for deriving evidence-based climate adaptation measures and informing regional-level sustainable development plans.

3. RESULT AND DISCUSSION

Based on a close comparison between the two graphical representations for the daily maximum and monthly average temperature in East Java for the period spanning 2025 through 2050, it can be said with absolute certainty that the region is destined to experience a gradually revealing long-term trend toward warming. Both visual depictions, computer-simulated through a forecasting program, share a consistent trend towards upward temperature within the 25-year timespan.

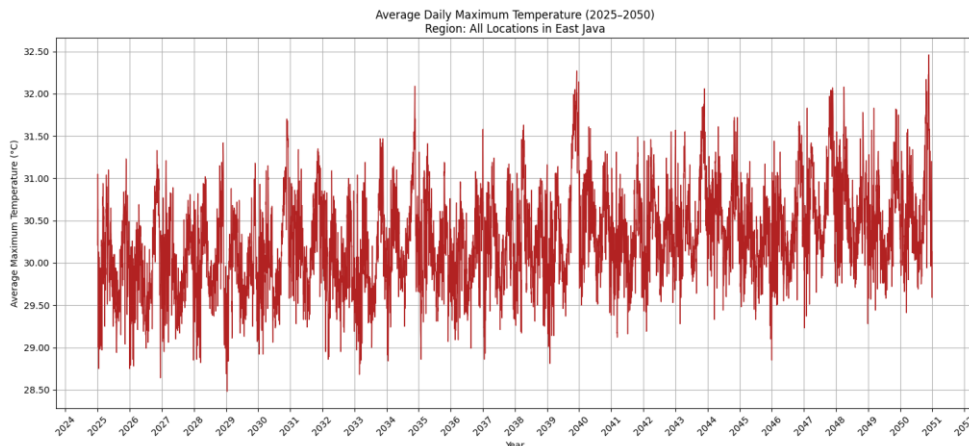


Figure 3. Average Daily Maximum Temperature East Java (2025 – 2050)

The first map, plotting the Average Daily Maximum Temperature, has extreme day-to-day temperature variations, but it still has two overall patterns. First, there is a clear annual cycle, in which temperatures are highest (often over 31.00°C) and lowest (about 29.00°C). Second, and importantly, a clear upward trend. Later-season max temperatures in the second half of our forecast period (2040–2050) are all greater than in the first half (2025–2035), with many peaks well over 32.00°C.

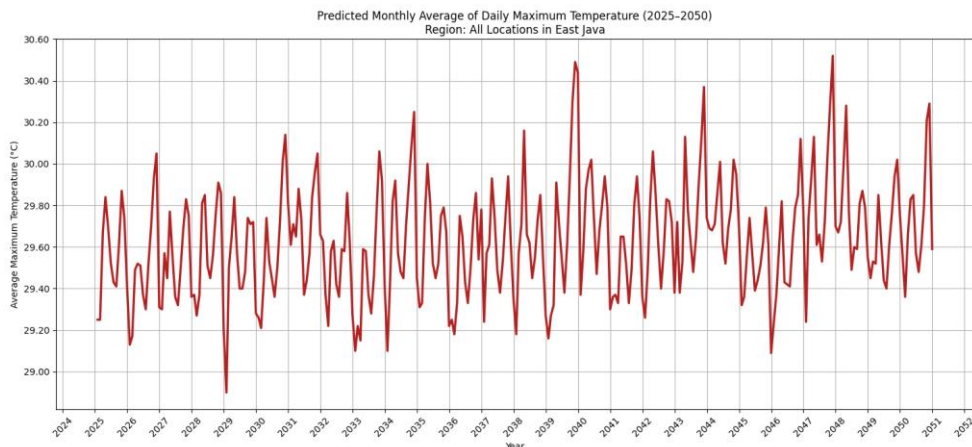


Figure 4. Predicted Monthly of Daily Maximum Temperature East Java (2025 – 2050)

This warming trend is further clarified by the second graph, the Predicted Monthly Average of Daily Maximum Temperature. By averaging the monthly data, short-term fluctuations are smoothed out, making the underlying trend more prominent. This graph also displays a stable seasonal cycle, but what is most evident is the strong long-term warming trend. Peak monthly temperatures in the latter period (2040–2050) are substantially higher than in the early years, with several peaks exceeding 30.40°C. The highest peak in the entire forecast period occurs around the year 2040, reaching approximately 30.50°C. This finding reinforces the conclusion that East Java will face progressive and substantial warming in the coming decades, potentially leading to more frequent and intense heat episodes.

1.3 Temporal Trend Analysis

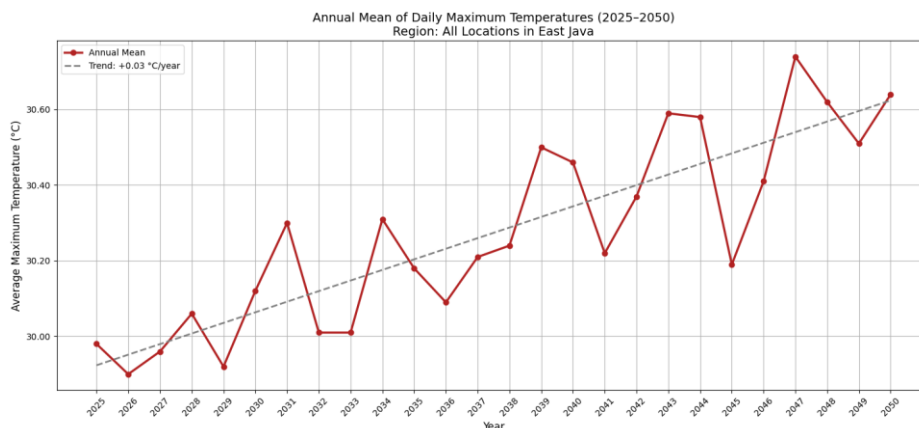


Figure 5. Annual Mean of Daily Maximum Temperatures All Location in East Java (2025 – 2050)

3.3.1 Annual Trends

The graph of annual average temperatures offers the clearest indication of a long-term warming trend in East Java, as projected by the model. While year-to-year variability is

evident—with cooler years such as 2032 and 2045, and significantly warmer years like 2030, 2040, and the record high in 2047—the linear regression analysis, represented by the trend line, unmistakably points to a significant upward trajectory. The dashed trend line on the graph suggests an average annual temperature increase of approximately $+0.03^{\circ}\text{C}$ per year.

At this rate, the projected warming per decade amounts to around 0.3°C ($0.03^{\circ}\text{C} \times 10$). This implies that the 2040s will be considerably warmer compared to the 2020s. Over the full projection period of 26 years (2025–2050), the total expected temperature increase is approximately 0.78°C ($0.03^{\circ}\text{C} \times 26$). The linear regression analysis supporting this trend provides strong statistical evidence that the observed warming is not a result of random fluctuations but rather reflects a systematic and persistent pattern—consistent with the assumptions of a high-emissions scenario, such as RCP 8.5, which underpins this study.

Recent observations and literature further support this projected trend. According to a 2022 Kompas report citing BMKG analysis, the northern part of Java—including sections of East Java—has experienced a surface temperature rise of more than 0.3°C per decade, equivalent to $+0.03^{\circ}\text{C}$ per year, which aligns exactly with the projection produced in this study (Arif, 2022). Similarly, (Zakariyah et al., n.d.) examined climate projections in the Upper Brantas sub-watershed and found that the RCP 8.5 scenario leads to significantly greater temperature increases than RCP 4.5, reinforcing the use of a high-emission scenario for East Java. (Amalia et al., 2025) also reported that RCP 8.5 projects stronger warming trends in Tuban and Malang compared to RCP 4.5. These studies confirm that the projected warming of $+0.78^{\circ}\text{C}$ over 2025–2050 is not only plausible but also aligned with regional empirical observations and recent climate model outputs under similar emission trajectories.

3.3.2 Seasonal Variations

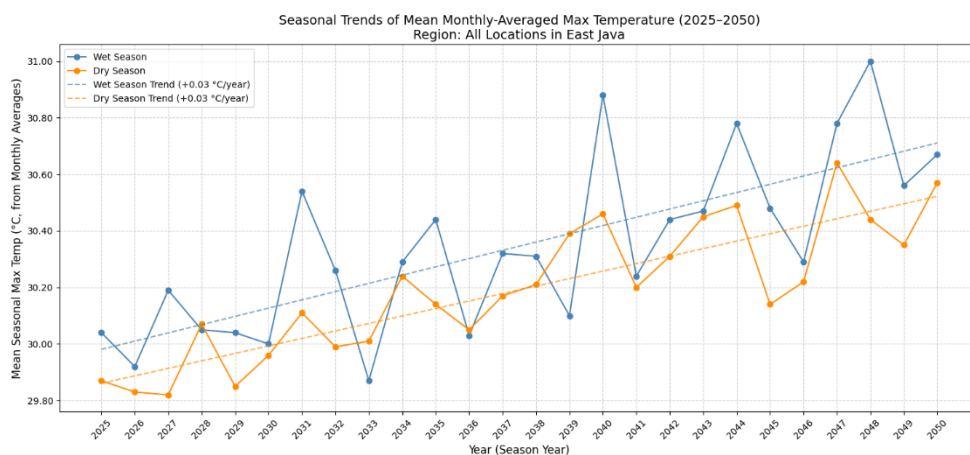


Figure 6. Annual Seasonal of Daily Maximum Temperature Trends All Location in East Java (2025 – 2050)

A seasonal-scale analysis reveals a significant warming pattern for both the Wet and Dry Seasons in East Java through 2050. One of the most striking observations from the graph is that average maximum temperatures during the Wet Season (blue line) are often projected to surpass those of the Dry Season (orange line). This pattern is particularly evident in peak years

such as 2031, 2040, and 2048, when Wet Season temperatures far exceed those in the Dry Season. Although this phenomenon may seem counterintuitive, it is climatologically explainable. High maximum temperatures during the Wet Season are often driven by intense solar radiation during the morning and early afternoon hours—before the onset of raincloud formation—which is further intensified by elevated atmospheric humidity (Ananta et al., 2024). High humidity acts as a thermal blanket, trapping heat in the lower atmosphere and leading to increased surface temperatures (Putra et al., 2025). This mechanism has been frequently cited by Indonesia's Meteorological Agency (BMKG) as a key reason behind the hot and stifling conditions commonly experienced during the rainy season (Rosa, 2023).

When examining long-term trends, the linear regression analysis uncovers a critical insight. Contrary to the assumption that warming rates might differ between seasons, the data indicate that both the Wet and Dry Seasons are warming at an identical rate of $+0.03^{\circ}\text{C}$ per year. However, despite this shared rate of increase, the trend lines (dashed) show that by the end of the projection period (e.g., 2045–2050), Wet Season temperatures consistently remain above those of the Dry Season. This suggests that although both seasons are warming at the same pace, the Wet Season is systematically projected to become the warmer of the two in terms of average maximum temperatures. This seasonal shift signals the emergence of a new climate risk, in which periods that traditionally offered relief from extreme heat may instead pose additional challenges due to the compounded effects of heat and high humidity.

Recent climatological studies support this observed and projected warming pattern in East Java. The World Bank Climate Change Knowledge Portal estimates that Indonesia may experience a temperature rise of $0.8\text{--}1.4^{\circ}\text{C}$ by the 2050s, affirming a nationwide warming trajectory consistent with this study's findings. Furthermore, (Hendrawan et al., 2025) reports historical warming trends across Indonesia of $0.18\text{--}0.24^{\circ}\text{C}$ per decade under SSP5-8.5, which approximates $0.018\text{--}0.024^{\circ}\text{C}$ per year, a value comparable to the $+0.03^{\circ}\text{C}/\text{year}$ trend derived in this research. Notably, (Ananta et al., 2024) found that East Java experienced an average warming of $+1^{\circ}\text{C}$ over 34 years, or roughly $+0.03^{\circ}\text{C}/\text{year}$, reinforcing the reliability of the model's seasonal warming projections.

These findings also align with evidence that Wet Seasons are becoming increasingly warm, contrary to traditional expectations. (Ananta et al., 2024) observed that higher humidity during the rainy season leads to warmer surface temperatures compared to the Dry Season, a counterintuitive pattern that this study also uncovers. Likewise, (Fauziah, 2020) explains that high humidity levels before rainfall release latent and sensible heat, intensifying the perception of heat. This condition, commonly referred to as "panas gerah" in Indonesian climate literature, indicates that rainy seasons may no longer serve as a cooling buffer but could instead become a period of elevated heat stress.

This shift is further compounded by studies such as (Roem et al., 2024), which project that Dry Seasons will become drier and Wet Seasons more intense, with shorter durations but higher daily rainfall, contributing to a compressed but humid monsoon season. (Hendrawan et al., 2025) highlights that southern Indonesian regions, including East Java, are experiencing longer dry periods and shorter yet more humid wet periods, increasing the risk of compounded climate stress.

In sum, the projected convergence of high temperatures and persistent humidity during the Wet Season poses an emergent climate risk for East Java—transforming the once temperate monsoon period into a period of oppressive heat, consistent with both empirical observations and recent climate projections.

3.4 Spatial Distribution Analysis

3.4.1 Spatial Mapping of Maximum Temperature

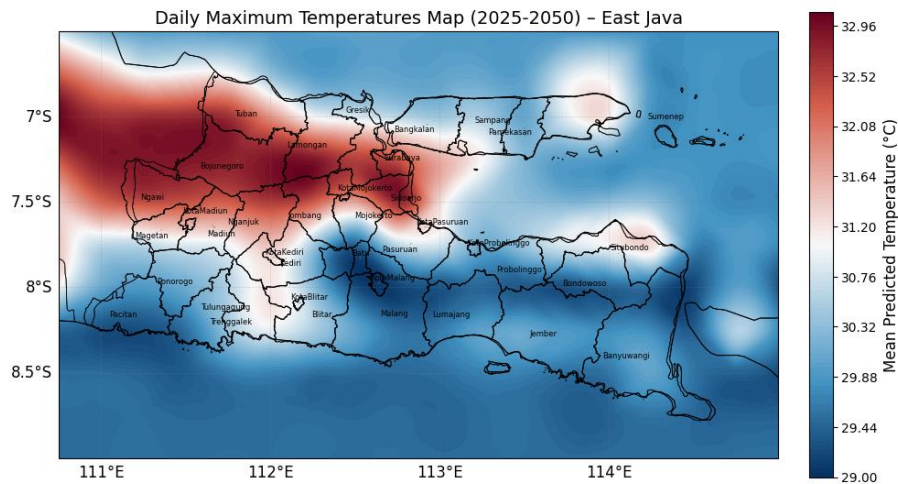


Figure 7. Daily Maximum Temperatures Map East Java (2025-2050)

This spatial distribution map provides a clear illustration of the projected pattern of average maximum temperatures across East Java during the 2025–2050 period. The dominant pattern reveals a concentration of extreme heat (indicated in deep red) in the northern and northwestern parts of the province, in contrast to significantly cooler regions (shown in blue) across the southern, central, and far eastern areas.

Table 2. Cities with the Highest Maximum Temperatures

City	Daily Maximum Temperature (°C)
Bojonegoro	32.86
Sidoarjo	32.73
Ngawi	32.38
Surabaya	32.33
Jombang	32.30

According to supporting tabular data, the regions with the highest projected average maximum temperatures are consistently Bojonegoro (32.86°C), Sidoarjo (32.73°C), Ngawi (32.38°C), Surabaya (32.33°C), and Jombang (32.30°C). Geographically, these areas are situated within lowland zones along the northern coast (Pantura) and the Bengawan Solo River basin. In contrast, cooler regions such as Bondowoso, Pacitan, and Malang are located in highland or mountainous areas in the central and southwestern parts of the province (Abdullah et al., 2025).

This spatial pattern is both logical and verifiable through geographical and urbanization-related factors. The first validation relates to topography: temperatures are naturally lower in elevated areas such as Malang, Batu, and the Ijen Highlands (Bondowoso), while lowland coastal zones inherently experience higher temperatures. The second explanation—highly relevant for understanding extreme heat in areas like Surabaya and Sidoarjo—concerns the Urban Heat Island (UHI) effect (Abdullah et al., 2025). The Gerbangkertosusila metropolitan area (Gresik, Bangkalan, Mojokerto, Surabaya, Sidoarjo, Lamongan) is a densely populated and industrialized corridor (Larasati et al., 2023). The prevalence of concrete and asphalt surfaces, combined with heat generated by industrial activity and traffic emissions, leads to greater absorption and re-radiation of solar energy compared to rural areas. This UHI effect significantly elevates local temperatures, and it appears that the predictive model has effectively captured this signal—helping to explain why these urban centers are projected to emerge as major “hotspots” under future climate scenarios.

3.4.2 Anomaly Temperature Analysis

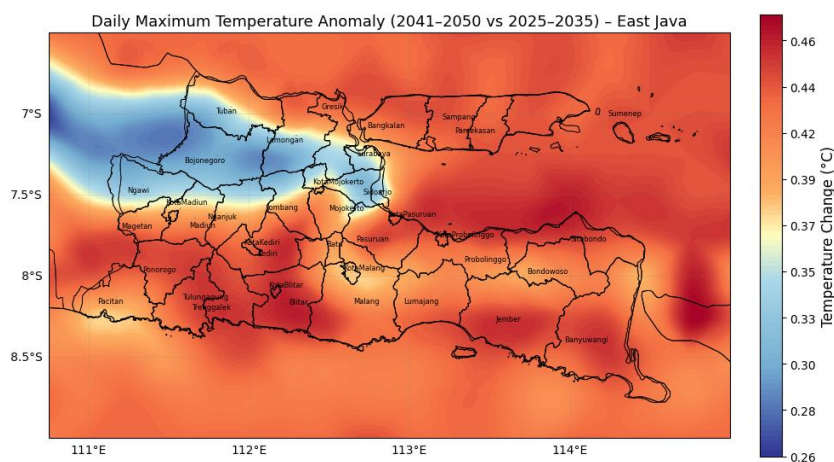


Figure 8. Anomaly Temperature Map East Java (2041-2050 vs 2025-2035)

This temperature anomaly map illustrates the spatial pattern of both the rate and magnitude of maximum temperature increases across East Java, by comparing projected averages for the late period (2041–2050) with those of the early period (2025–2035).

Table 3. Top 10 locations with the highest temperature anomaly

City	2025-2035 (°C)	2041-2050 (°C)	Anomaly (°C)
Blitar	30.45	30.9	0.45
Situbondo	30.82	31.27	0.45
Tulungagung	30.43	30.88	0.45
Bangkalan	30.20	30.64	0.44
Jember	29.60	30.05	0.44
Pasuruan	30.48	30.92	0.44
Trenggalek	29.82	30.26	0.44
Sumenep	30.78	31.22	0.44
Sampang	30.30	30.74	0.44
Kediri	30.76	31.19	0.44

The map clearly demonstrates that warming is not spatially uniform; areas shaded in orange to red represent regions experiencing the most rapid increases. Based on supporting data, the primary "hotspots" or high-priority regions for adaptation due to accelerated warming—include Blitar, Situbondo, and Tulungagung (each showing a rise of 0.45°C), as well as Jember, Pasuruan, Kediri, and several others (with increases of 0.44°C).

In coastal areas such as Pasuruan and Situbondo, the acceleration in warming is strongly influenced by faster increases in Sea Surface Temperature (Sea et al., 2025). Meanwhile, in intensively cultivated agricultural regions such as Blitar and Tulungagung, a dominant mechanism appears to be the soil moisture–temperature feedback (Qiao et al., 2023). In these areas, drier soil conditions result in a larger portion of solar energy being used to heat the air rather than to evaporate moisture, thereby amplifying local warming rates. This evidence highlights the critical need for spatially targeted climate adaptation strategies—approaches that consider not only absolute temperature levels, but also the speed of environmental change and the specific local mechanisms driving warming. Failure to account for these dynamics may leave certain vulnerable regions underprepared for the escalating impacts of climate change.

3.5 Implications of Projected Warming

The predictive modeling results for East Java over the 2025–2050 period underscore critical multidimensional implications, emphasizing the urgency of informed and spatially targeted climate adaptation policies. With a clear warming trend of +0.03°C per year, the province faces mounting challenges across sectors including agriculture, health, urban development, and

environmental management. These findings are no longer speculative projections; they constitute a strategic roadmap for immediate action in both mitigation and adaptation.

Sector-specific impacts make the urgency of action especially apparent. In agriculture, areas like Blitar and Tulungagung—major food-producing regions—are projected to experience the fastest warming rates, with anomalies reaching $+0.45^{\circ}\text{C}$. This increase, driven by soil moisture–temperature feedback mechanisms, threatens crop productivity and poses a direct risk to regional food security (Ansari et al., 2021). In urban zones, the Gerbangkertosusila metropolitan region, including Surabaya and Bojonegoro, emerges as a projected hotspot for absolute maximum temperatures due to the Urban Heat Island (UHI) effect (Hasyim et al., 2025). This trend is likely to elevate energy demand and degrade urban livability, particularly in high-density, industrialized areas (Sari, 2021). Meanwhile, a unique finding of this study is the seasonal shift in climate, in which the Wet Season is projected to become hotter than the Dry Season. This shift introduces a new category of health risks from extreme humidity combined with high temperatures—commonly referred to as “humid heat”—which could lead to an increase in heatstroke cases and vector-borne diseases (Vensya Sitohang et al., 2021).

The real challenge lies in translating these insights into concrete actions. For agriculture, anomaly maps should be used by regional agencies and farmer groups to assess land vulnerability, adjust planting calendars, promote heat-resilient crop varieties, and deploy water-saving irrigation technologies. Health authorities can utilize daily temperature data to establish early warning systems for heatwaves and develop treatment protocols for heat-related illnesses in vulnerable districts. Urban and spatial planners must integrate climate data into revised spatial plans (RTRW) and strategic environmental assessments (KLHS), especially in light of the “dual-risk” zones—areas facing both extreme heat and rapid warming. Such integration is critical and should be guided by regulatory references such as those discussed by (Tyndall, 2024; Umam, 2021), ensuring that development policies are aligned with long-term climate resilience goals. In cities, this could mean updating building codes to require climate-resilient materials and minimum percentages of green open spaces.

In the end, this study affirms that climate adaptation in East Java must shift from reactive responses to proactive, science-based, and cross-sectoral strategies. Building long-term regional resilience will require coordinated collaboration among governments, academic institutions, the private sector, and local communities to address the accelerating challenges of climate change.

3.6 Model Strengths and Limitations

Based on the analysis conducted, the Support Vector Regression (SVR) model has demonstrated strong potential in projecting the dynamics of daily maximum temperatures across East Java Province through 2050. Its primary strength lies in its ability to capture complex and significant climate patterns. Notably, the model effectively simulates long-term warming trends, estimating a gradual increase of $+0.03^{\circ}\text{C}$ per year. It also captures inter-seasonal variability, revealing a critical insight: although the rate of warming is similar between the wet and dry seasons, the projected absolute temperatures during the wet season are expected to be higher. From a spatial perspective, the SVR model identifies key features such as absolute temperature “hotspots” (e.g., Surabaya and Sidoarjo), likely influenced by the Urban Heat

Island (UHI) effect, as well as mapping regions experiencing the most rapid warming anomalies.

Despite its strengths, this study acknowledges several limitations that point toward future research directions. One notable constraint of the SVR model is its tendency to generate more conservative or smoothed predictions. This characteristic may limit its responsiveness to brief, extreme temperature fluctuations—such as sudden heat spikes or sharp cooling episodes. Future work could address this by incorporating additional meteorological parameters such as precipitation and humidity, and by comparing projections across multiple climate scenarios, such as RCP 4.5 or various SSP pathways, to enrich the assessment of climate-related risks. Overall, the SVR model has proven effective in delivering both spatially and temporally detailed projections, laying a strong foundation for more comprehensive climate impact analysis.

4. CONCLUSION

Based on the analysis, this study concludes that the Support Vector Regression (SVR) model successfully projects a systematic and statistically significant warming trend across East Java through 2050 under the RCP 8.5 scenario. The model reveals an average annual temperature increase of $+0.03^{\circ}\text{C}$ per year, amounting to an estimated total rise of approximately 0.78°C over the 2025–2050 period. Spatially, the model accurately captures two distinct risk patterns: (1) persistent absolute temperature “hotspots” in the lowland northwestern areas such as Bojonegoro (32.86°C) and Surabaya (32.33°C), largely driven by the Urban Heat Island (UHI) effect; and (2) regions with the fastest warming anomalies along the southern and coastal zones, particularly Blitar and Situbondo (both $+0.45^{\circ}\text{C}$), likely influenced by the interaction of sea surface temperatures and soil moisture dynamics. One of the study’s most critical findings is the model’s ability to uncover that although both wet and dry seasons are warming at a similar rate, the wet season is projected to become hotter than the dry season, indicating an emerging shift in climate risk patterns.

Given these findings, future research is strongly encouraged to explore deep learning approaches such as Long Short-Term Memory (LSTM) networks, which may offer superior performance in capturing long-term dependencies in time series data. Model accuracy could also be substantially enhanced by incorporating additional predictors aligned with this study’s insights—such as air humidity (to better analyze intensified wet-season warming), land cover (to sharpen UHI assessments), and sea surface temperature (SST). This integrative approach would not only yield more precise projections but also strengthen causal inferences, thereby supporting the development of more effective, evidence-based climate adaptation strategies for the most vulnerable regions in East Java.

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