AKADEMIYA2063

CACCI
COMPREHENSIVE ACTION FOR CLIMATE CHANGE INITIATIVE

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CACCI FIELD NOTES

Examining Land Surface Temperature Dynamics in Freetown, Sierra Leone, amid the Climate Crisis

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About the CACCI Field Notes

AKADEMIYA2063 CACCI Field Notes are publications by AKADEMIYA2063 scientists and collaborators based on research conducted under the Comprehensive Action for Climate Change Initiative (CACCI) project. CACCI strives to help accelerate the implementation of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) by meeting the needs for data and analytics and supporting institutional and coordination capacities. In Africa, CACCI works closely with the African Union Commission, AKADEMIYA2063, the African Network of Agricultural Policy Research Institutes (ANAPRI), and climate stakeholders in selected countries to inform climate planning and strengthen capacities for evidence-based policymaking to advance progress toward climate goals.

Published on the AKADEMIYA2063 website (open-access), CACCI Field Notes provide broad and timely access to significant insights and evidence from our ongoing research activities in the areas of climate adaptation and mitigation. The data made available through this publication series will provide evidence-based insights to practitioners and policymakers driving climate action in countries where the CACCI project is being implemented.

AKADEMIYA2063's work under the CACCI project contributes to the provision of technical expertise to strengthen national, regional, and continental capacity for the implementation of NDCs and NAPs.

AKADEMIYA2063 is committed to supporting African countries in their efforts against climate change through provision of data and analytics using the latest available technologies. In this Field Note, AKADEMIYA2063 researchers examined land surface temperature (LST) anomalies in Freetown and its surrounding region, identifying areas with the most prominent temperature divergences by matching temperature anomalies to land use and land cover maps over the last ten years.

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About AKADEMIYA2063

AKADEMIYA2063 is a pan-African non-profit research organization with headquarters in Kigali, Rwanda and a regional office in Dakar, Senegal. Inspired by the ambitions of the African Union's Agenda 2063 and grounded in the recognition of the central importance of strong knowledge and evidence-based systems, the vision of AKADEMIYA2063 is an Africa with the expertise we need for the Africa we want. This expertise must be responsive to the continent's needs for data and analysis to ensure high-quality policy design and execution. Inclusive, evidence-informed policymaking is key to meeting the continent's development aspirations, creating wealth, and improving livelihoods.

AKADEMIYA2063's overall mission is to create, across Africa and led from its headquarters in Rwanda, state-of-the-art technical capacities to support the efforts by the Member States of the African Union to achieve the key goals of Agenda 2063 of transforming national economies to boost economic growth and prosperity.

Following from its vision and mission, the main goal of AKADEMIYA2063 is to help meet Africa's needs at the continental, regional and national levels in terms of data, analytics, and mutual learning for the effective implementation of Agenda 2063 and the realization of its outcomes by a critical mass of countries. AKADEMIYA2063 strives to meet its goals through programs organized under five strategic areas—policy innovation, knowledge systems, capacity creation and deployment, operational support, and data management, digital products, and technology—as well as innovative partnerships and outreach activities. **For more information**, visit www.akademiya2063.org.

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Table of Contents

1. Introduction

Tracking temperature anomalies in cities is crucial in the context of climate change and climate variability. Cities cover a fraction of the Earth's surface, but they contribute significantly to greenhouse gas (GHG) emissions, influencing local climates and global atmospheric conditions. Certain statistics show that built-up urban areas, including cities, towns, villages, roads, and other human infrastructures, comprise an estimated 1 percent of the Earth's surface (Roser 2024). Other data estimate that a little over one-half to two-thirds of global energy consumption, and almost 50-80 percent of global GHG emissions are directly and indirectly tied to urban economies (Muhammad Luqman 2023). The latter estimate points to the potential creation of a local climate in urban areas that could trigger temperature anomalies, making the pursuit of livelihoods in urban areas more difficult. In addition, high levels of GHG emissions could lead to an increase in health issues due to prolonged particle suspension in the lower atmosphere.

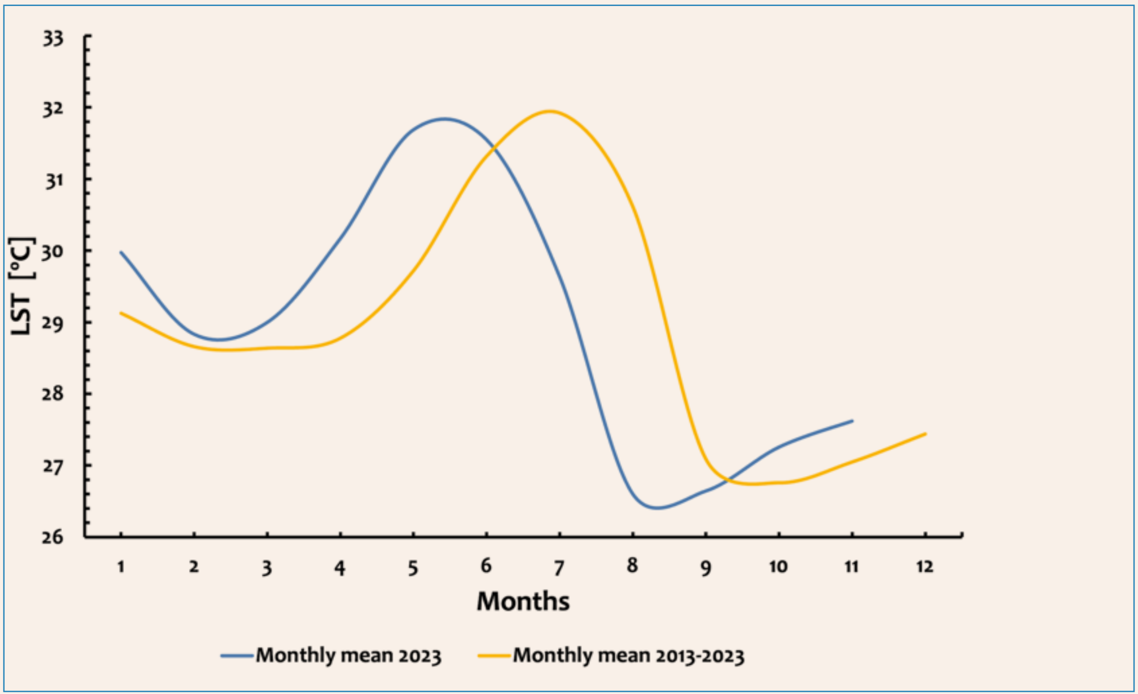
Anomalies can be attributed to disruptions in typical weather patterns, potentially stemming from natural variability and human-induced climate change. By monitoring these changes, urban planners and policymakers can identify trends, anticipate potential impacts on infrastructure, public health, and ecosystems, and implement adaptive strategies to mitigate harm. Furthermore, understanding urban heat dynamics is vital for building resilience against heat waves, which are becoming more frequent and severe due to climate change. This vigilance is essential for safeguarding the well-being of the urban population, which is projected to increase, amplifying the urban heat island effect. Tracking and addressing temperature deviations in urban areas is therefore vitally important.

A team of AKADEMIYA2063 researchers looked at land surface temperature (LST) anomalies in Freetown and its surrounding region (referred to as the Freetown region in this brief). We computed daily, weekly, monthly, and annual anomalies by comparing the temperature of any specific date with its average temperature over the last ten years. We then identified areas with the most prominent temperature divergences from the 10-year average by matching temperature anomalies to land use and land cover maps.

2. Freetown Region's Temperature Dynamics for the 2013-2023 Period

Computation of the average LST for each month in 2023 and comparison with the same month during the 2013-2023 period shows temperatures following the same general pattern, although there is an approximately two-month time shift from February to September. This means that there was almost no temperature increase in 2023 during that period in comparison to the 2013-2023 period. However, the time at which a certain temperature was recorded during the reference period shifted by about two months, as shown in Figure 1 below. This means that from February to mid-May, people would have experienced warmer weather than usual, while from June to September, they would have experienced cooler weather than usual. The curves also show warmer temperatures from mid-September to the end of the year in comparison to the reference period. Such information is essential for monitoring perceptions of temperatures as it could impact electricity consumption and public health, as well as inform the city's planning of activities.

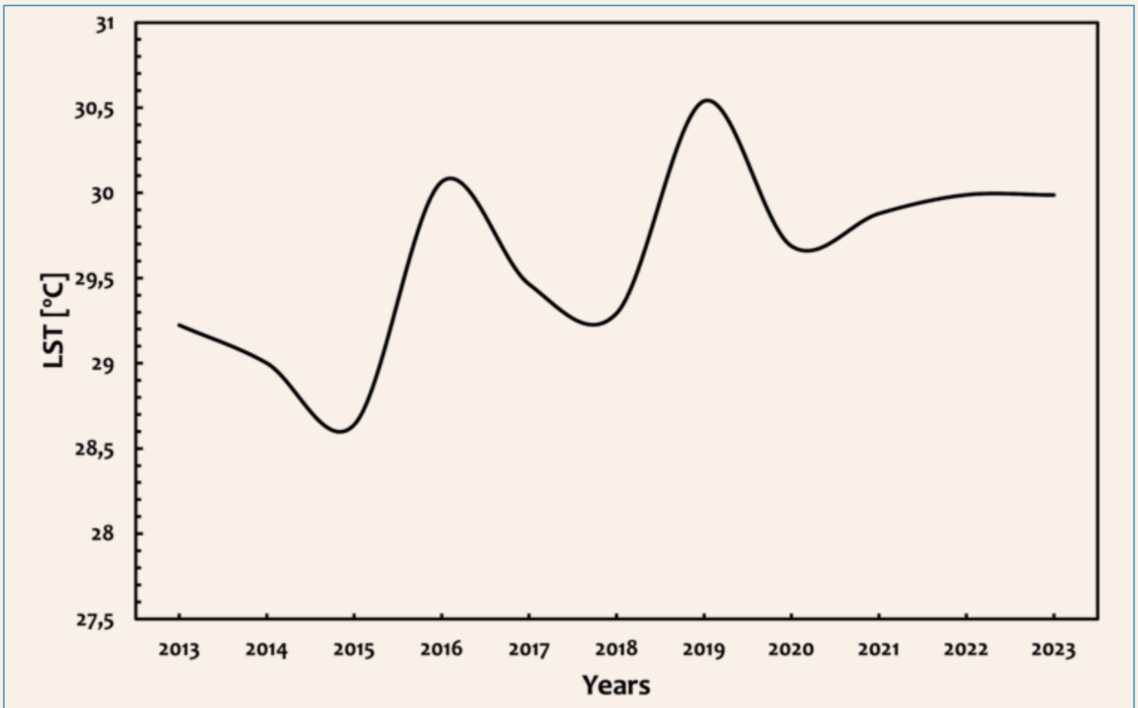
Figure 1: *Comparison between average land surface temperatures by month for 2023 and 2013-2023.*



Data source: MODIS dataset; Data processing and mapping: Authors.

On the other hand, average annual land surface temperatures of the Freetown region show an increasing trend with interannual oscillations (see Figure 2 below). Average annual temperatures do not return to their initial levels from one cycle to another. Instead, a new higher minimum temperature was set at the beginning of 2015 (28.5 °C), 2018 (29.2 °C), and 2020 (29.7 °C). From 2021 to 2023, average annual temperatures plateaued at about 30 °C. Further investigation is needed on the possible reasons for this situation.

Figure 2: *Annual trends for land surface temperatures during the 2013-2023 period.*



Data source: MODIS dataset; Data processing and mapping: Authors.

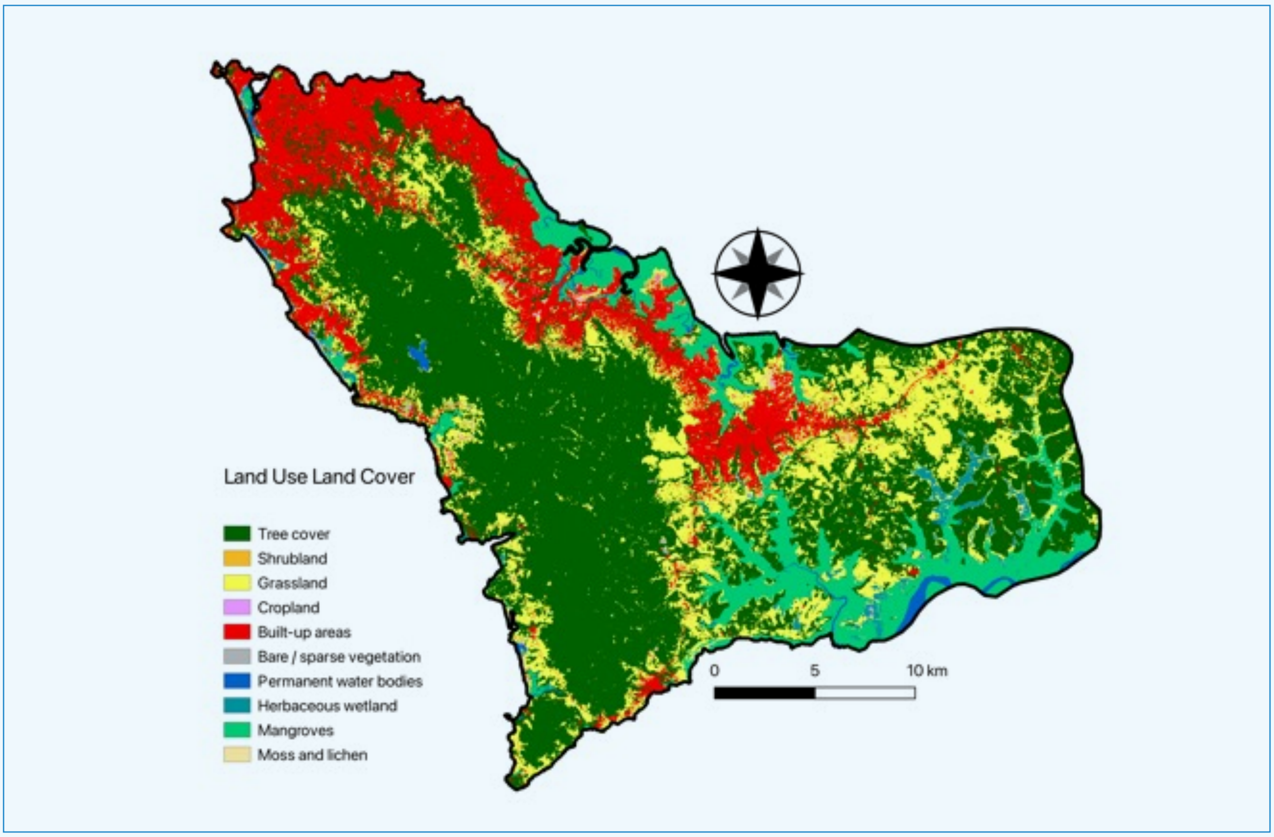
3. Freetown Region's Monthly Temperature Anomalies in 2023

Figure 4 represents LST anomalies for the Freetown region from January to June 2023. In climate science, an anomaly is a departure from a reference value or long-term average. A positive anomaly indicates that the observed temperature was warmer than the reference value, while a negative anomaly indicates cooler conditions. In our case, we computed the average temperature for each month and compared it with the average value of the same month during the 2013-2023 period. Key takeaways from this analysis follow:

- There is a persistent positive anomaly in the entire Freetown region, meaning average monthly temperatures in 2023 were higher than those in the reference period. The sustained positive anomalies across the region call for further investigation into the underlying causes and the development of potential mitigation strategies to manage impacts on the environment and human activities.

- The anomalies range from +0.7 °C to +1.8 °C, with a different spatial distribution from one month to another. The highest anomaly density was observed in May when even the Western Area National Park was warmer than usual. Given its distinct geographical shape, the latter may have played a role in March and April (see Figure 3 for the Freetown region land use and land cover compared with the maps in Figure 4).

Figure 3: *Land use and land cover map of the Freetown region.*

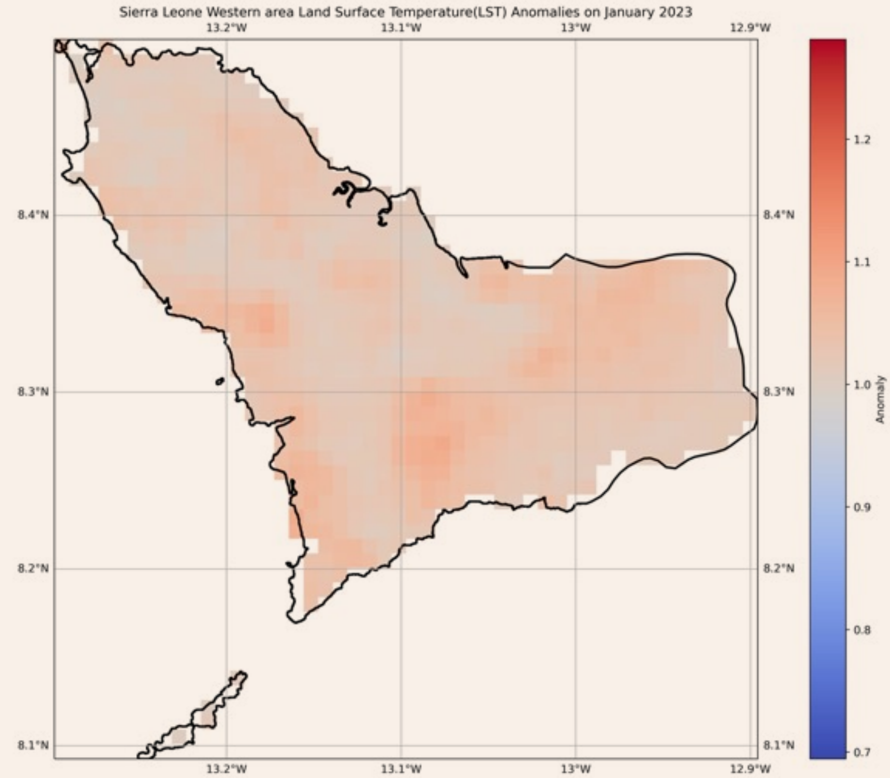


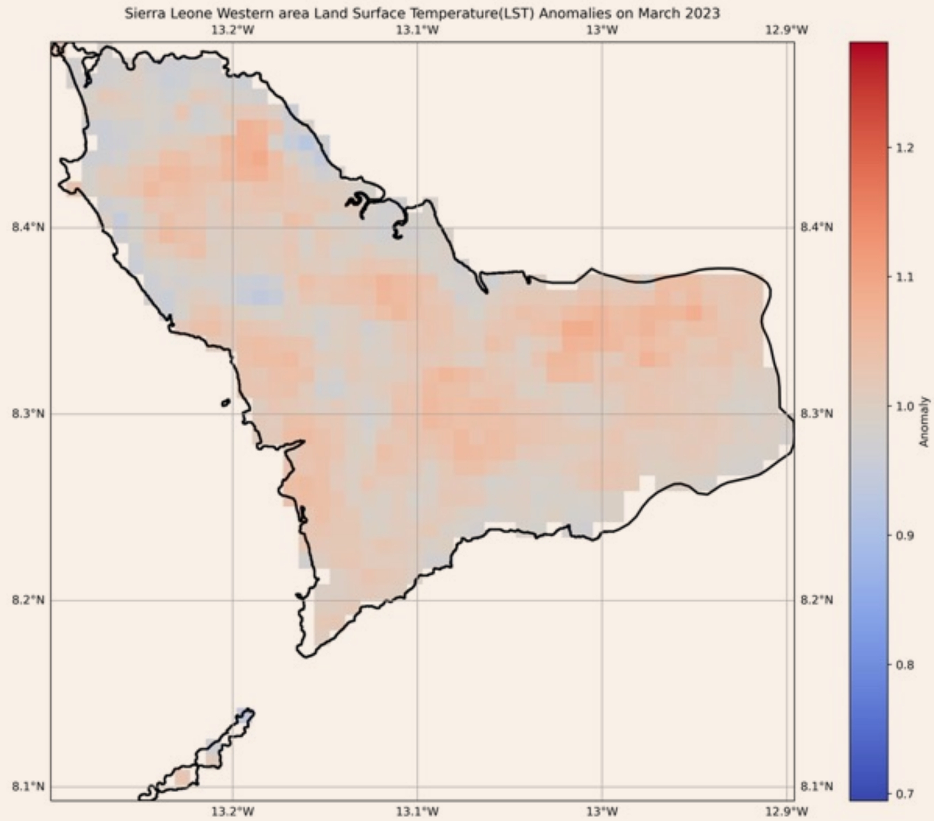
Data source: ESA WorldCover project (2021)/Contains modified Copernicus Sentinel data (year) processed by ESA WorldCover consortium; Data processing and mapping: Authors.

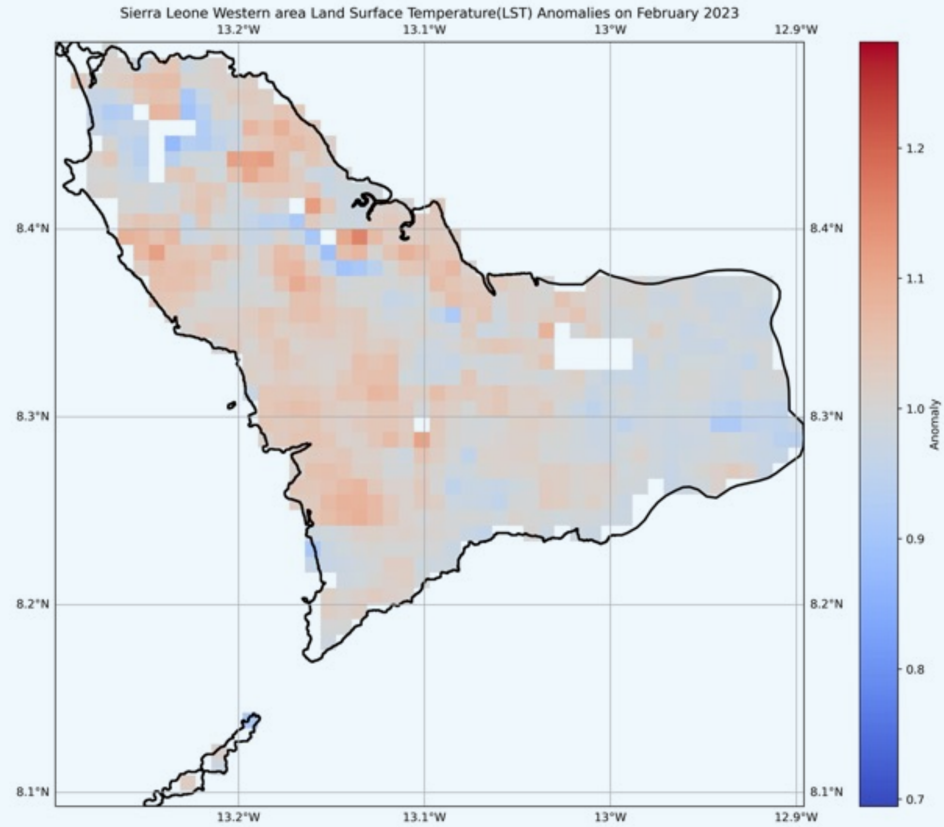
- The coastal zone mostly shows a positive temperature anomaly indicating that proximity to water did not have a cooling effect during the study period.

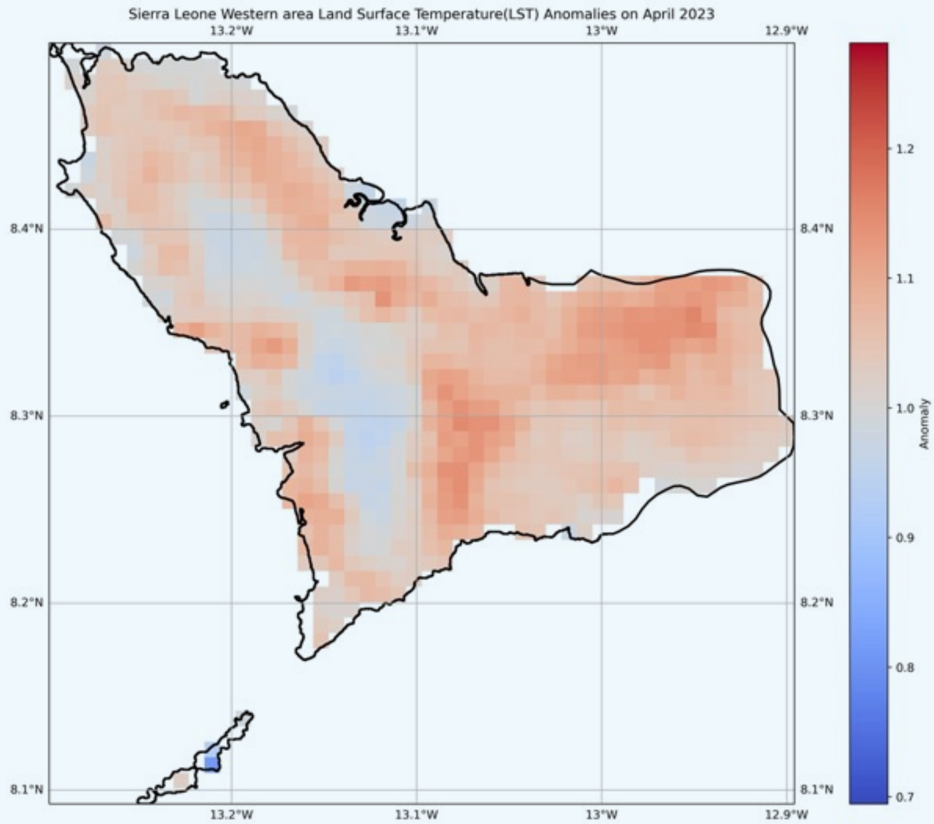
- Over the six months, the LST anomalies show an apparent increase in temperature for each month compared to the reference period. However, this trend could be influenced by several factors, including seasonal changes, local weather patterns, or broader climate phenomena. The continued persistence of positive LST anomalies could have various implications, including heat stress on the population and biodiversity, changes in precipitation patterns, and potential impacts on the hydrological cycle.

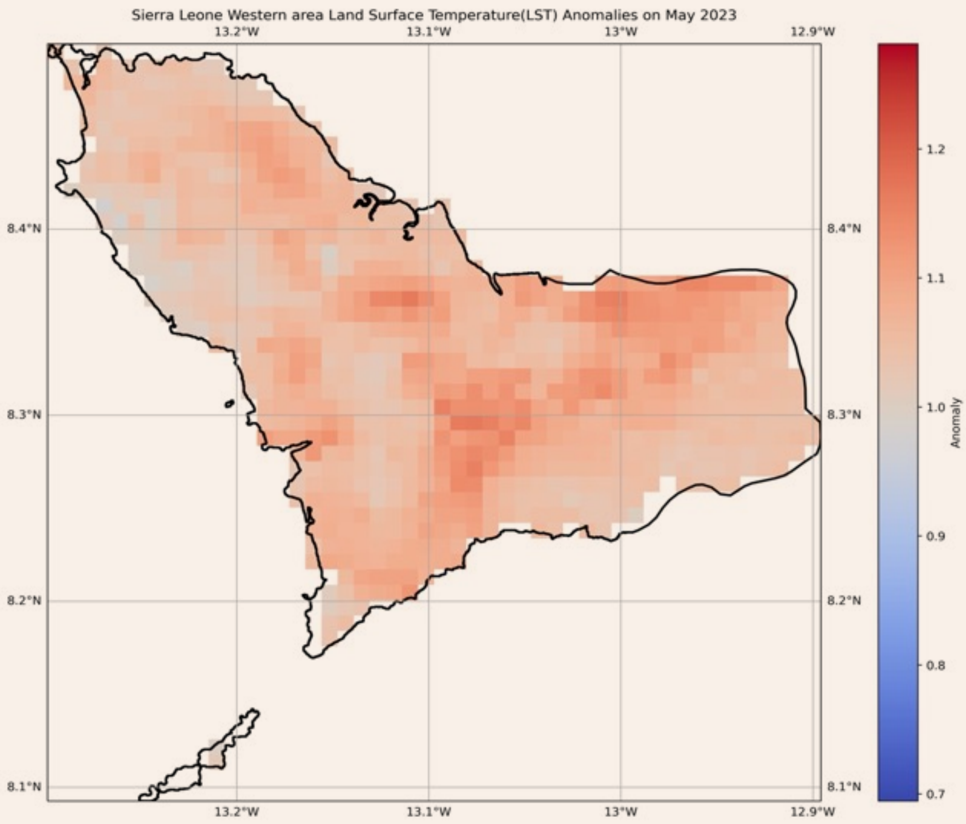
Figure 4: *Land surface anomalies in the Freetown region from January to June 2023.* *A positive anomaly means a warmer average monthly temperature was recorded for that month in 2023 in comparison to the average temperature for that same month over the ten-year reference period. In contrast, a negative anomaly means a cooler temperature. Data processing and mapping: Authors.*

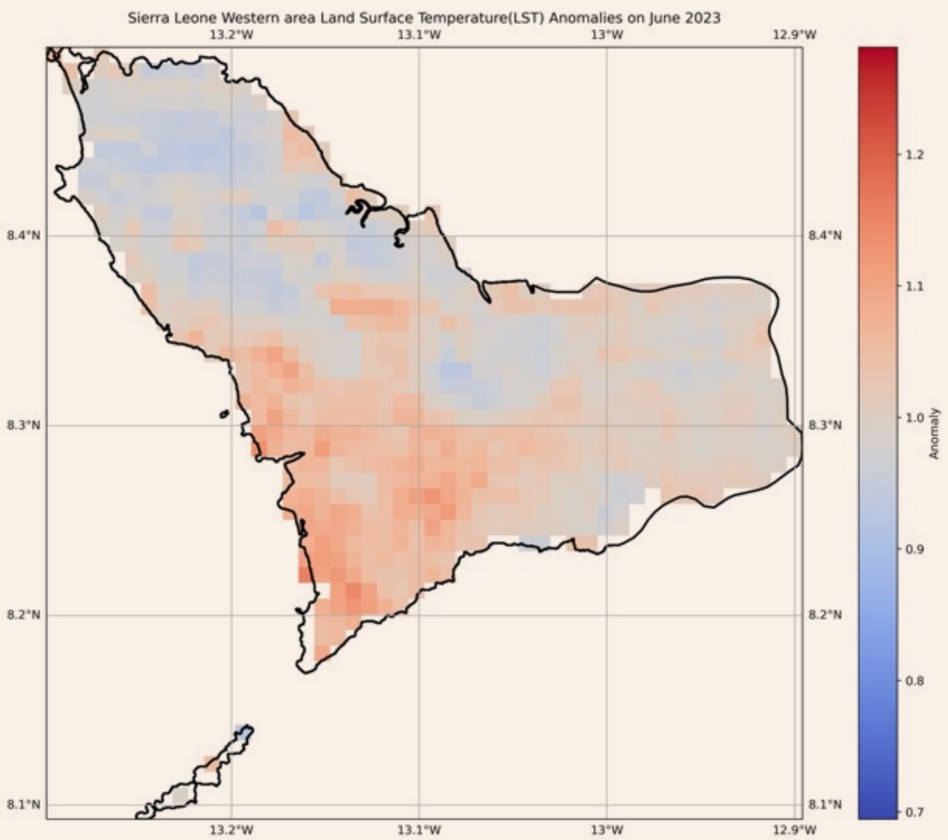





Sierra Leone Western area Land Surface Temperature(LST) Anomalies on February 2023
13.2°W
13.1°W
13°W
12.9°W
8.4°N
8.3°N
8.2°N
8.1°N
Anomaly
1.2
1.1
1.0
0.9
0.8
0.7


Sierra Leone Western area Land Surface Temperature(LST) Anomalies on April 2023
13.2°W
13.1°W
13°W
12.9°W
8.4°N
8.3°N
8.2°N
8.1°N
Anomaly
1.2
1.1
1.0
0.9
0.8
0.7


Sierra Leone Western area Land Surface Temperature(LST) Anomalies on May 2023
13.2°W
13.1°W
13°W
12.9°W
8.4°N
8.3°N
8.2°N
8.1°N
1.2
1.1
1.0
0.9
0.8
0.7
Anomaly


Sierra Leone Western area Land Surface Temperature(LST) Anomalies on June 2023
13.2°W
13.1°W
13°W
12.9°W
8.4°N
8.3°N
8.2°N
8.1°N
1.2
1.1
1.0
0.9
0.8
0.7
Anomaly

4. Forecasting Precipitation Data with the Deep Long-Horizon Machine Learning Model

In addition to the analysis presented above, we conducted a forecasting exercise to provide a forward-looking feature related to temperature dynamics in the region of interest. We used the Time series Dense Encoder (TiDE) model to forecast temperature data for western Sierra Leone. The model uses advanced techniques in time series analysis and neural networks to capture intricate patterns such as covariates within time series data.

The experimental phase involved training the model on historical temperature data retrieved from hourly ERA5 (ECMWF Reanalysis version 5). The prediction period spanned two months, from September to November 17, 2023. To optimize the model's performance, a comprehensive grid search was conducted to fine-tune its parameters. Upon completion of the training and subsequent conducting of prediction exercises, the experimental results demonstrated a remarkable goodness of fit. In Figure 5 (a), the actual temperature values align closely with the predicted values, indicating the model's ability to capture the underlying patterns in the time series data. In addition, the differences between actual and predicted values were analyzed to quantify the model's performance. Most of the differences fell within the narrow interval of –1°Cand +1°C (see Figure 5 (b)), highlighting the model's precision in forecasting temperatures for western Sierra Leone.

These findings underscore the effectiveness of the employed model architecture and parameter tuning strategy, contributing to advancements in time series forecasting for climatic variables such as temperature. The forecast shown below corresponds to only one pixel. Future analysis will focus on providing similar anticipatory approaches for all pixels in the region of interest.

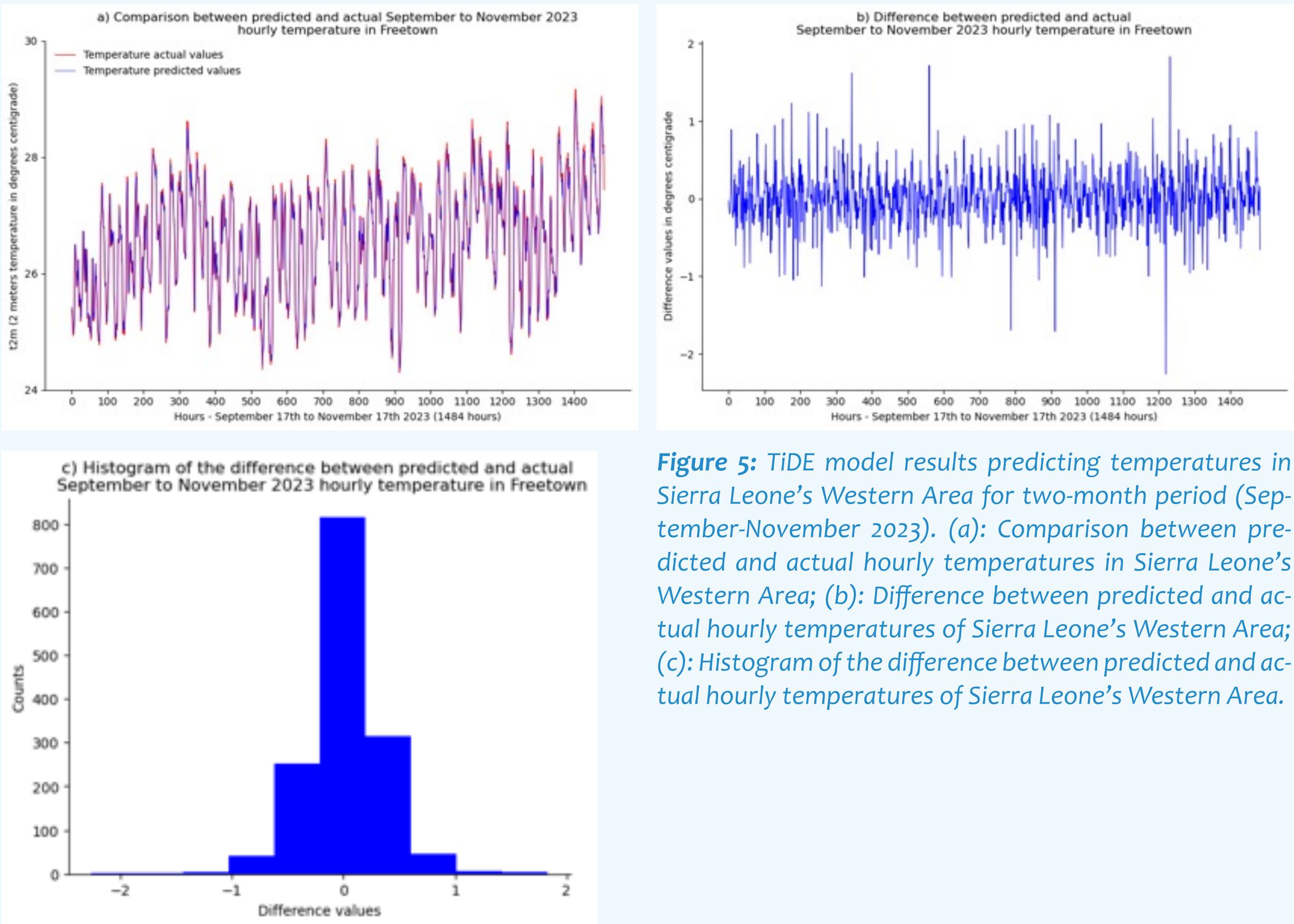


Figure 5: *TiDE model results predicting temperatures in Sierra Leone's Western Area for two-month period (September-November 2023). (a): Comparison between predicted and actual hourly temperatures in Sierra Leone's Western Area; (b): Difference between predicted and actual hourly temperatures of Sierra Leone's Western Area; (c): Histogram of the difference between predicted and actual hourly temperatures of Sierra Leone's Western Area.*

5. Conclusion

Building a data bridge between policymakers and communities, especially in urban areas, is crucial for informed and effective decision-making. Such a bridge facilitates the flow of vital information, ensuring that the unique needs and perspectives of diverse urban populations are accurately represented in policy formulation. In a rapidly evolving urban landscape, where challenges such as population growth, environmental sustainability, and socio-economic disparities call for nuanced solutions, this two-way data exchange enables policymakers to craft targeted strategies that are both impactful and culturally sensitive. Further, by empowering communities with a voice in decision-making, this data bridge fosters a sense of ownership and responsibility, leading to greater public engagement and support for policy initiatives. In essence, the data bridge serves as a crucial tool for creating more inclusive, adaptive, and resilient urban environments, where policies are not only shaped by realities on the ground, but also bolstered by the active participation and insights of the community members they are designed to serve.

In this context, a team of scientists at AKADEMIYA2063 is exploring land surface temperature dynamics in African cities to better support such synergies. The frequency with which the data is collected and analyzed, as well as its spatial granularity allows us to better understand the changing bio-geophysical dynamics and the areas that require targeted intervention planning.

Disclaimer

This document uses publicly available satellite remote sensing data. Data content clipped to the Freetown region administrative borders as the region of interest might be added for illustrative purposes. AKADEMIYA2063 uses the Freetown region shapefiles mentioned above solely for constraining the data map to the geographical extent of the region of interest. The boundaries, names, and designations shown on maps do not imply official endorsement or acceptance by AKADEMIYA2063.

6. References

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