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# Impact of El Niño and La Niña on Precipitation and Temperature Patterns in Nigerian Regions: A Case Study of Lagos and Port-Harcourt

**K. O. Olawale & E.O. Adetunji**
The Federal Polytechnic of Ede, Osun State, Nigeria
Olawale1@gmail.com

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**Abstract**

This study explores the impact of El Niño and La Niña events on local climate patterns in Nigeria, focusing specifically on the region of Lagos and Port-Harcourt. Utilizing ERA5 reanalysis data, including total precipitation (TP) and 2-meter air temperature (T2m), alongside NOAA ERSST v5 sea surface temperature (SST) anomalies, we investigate the correlations between SST anomalies in the Pacific and Atlantic Oceans and the weather variables in these regions. The objective is to elucidate how these global climate phenomena affect regional weather patterns in West Africa. Our analysis reveals significant alterations in precipitation and temperature patterns during El Niño and La Niña events, with distinct impacts observed in Lagos (a coastal region) and Port-Harcourt (another coastal city). These findings highlight the variability in climatic responses across different regions of Nigeria, depending on the intensity and duration of the events. This research enhances understanding of the mechanisms through which global climate phenomena influence local weather conditions, offering valuable insights for improving climate forecasts and informing effective adaptation strategies. The study contributes to the broader field of climate science by integrating global and regional climate data, emphasizing the importance of such analyses in developing nations for comprehensive weather and climate predictions.

**Keywords:** El Niño, La Niña, Climate patterns, Precipitation, Temperature, Sea surface temperature (SST), Climate variability, Pacific Ocean, Atlantic Ocean

## INTRODUCTION

**Background on El Niño and La Niña Events:** El Niño and La Niña are two opposing phases of the El Niño-Southern Oscillation (ENSO), a significant climate phenomenon characterized by periodic fluctuations in sea surface temperatures (SST) in the central and eastern tropical Pacific Ocean. El Niño, meaning "the boy" in Spanish, is associated with warmer ocean temperatures, while La Niña, or "the girl," is characterized by cooler-than-average SSTs. These events typically occur every two to seven years and can last from nine months to several years, significantly impacting global weather patterns and climate variability (Trenberth & Hoar, 1997). El Niño events are marked by a weakening of the trade winds, which allows warm water to shift eastward toward the Americas, disrupting normal oceanic and atmospheric circulation patterns. Conversely, La Niña events strengthen the trade winds, pushing warm water further west and enhancing upwelling of cold, nutrient-rich water along the coasts of South America. Both phenomena lead to dramatic changes in precipitation, temperature, and storm patterns across the globe (Collins et al., 2019).

**Overview of Their Global Impact on Weather Patterns:** The impacts of El Niño and La Niña are felt worldwide, influencing weather patterns, ecosystems, and economies. El Niño is often linked to increased rainfall and flooding in the eastern Pacific, while causing droughts in regions such as Southeast Asia and Australia. In contrast, La Niña typically brings about wetter conditions in Southeast Asia and drier conditions in the eastern Pacific, including parts of the Americas (Nicholson & Webster, 2007). During El Niño events, global average temperatures tend to rise, exacerbating the effects of climate change and leading to extreme weather events such as hurricanes, wildfires, and heatwaves (Cowan & Sullivan, 2015). The socio-economic consequences are profound, affecting agriculture, water resources, and public health. La Niña, while generally associated with cooler global temperatures, can also trigger severe weather events, including heavy rainfall and flooding in some regions, highlighting the complex interplay between these climate phenomena and global weather systems.

**Relevance to West Africa and Nigeria:** In West Africa, including Nigeria, El Niño and La Niña events have significant implications for regional climate and weather patterns. Nigeria, characterized by its diverse climate zones, different region experiences varying impacts from these global phenomena. For instance, coastal areas such as Lagos may see changes in rainfall patterns and sea surface temperatures, affecting local weather conditions. while regions like Port-Harcourt a core section of the Niger-delta may experience different effects, including shifts in precipitation and temperature extremes (Anyadike & Hughes, 2008). Understanding the influence of El Niño and La Niña on Nigeria's climate is crucial for several reasons. Firstly, it aids in predicting and mitigating the effects of these phenomena on agriculture, water resources, and infrastructure. Secondly, it provides insights into how global climate variability affects local weather patterns, helping to refine climate models and forecasts. Finally, this knowledge supports the development of effective climate adaptation strategies, essential for managing the impacts of climate variability and change in Nigeria.

**Objectives of the Study:** The primary objectives of this study are:

1) **To Analyse the Correlations**: Examine the correlations between sea surface temperature (SST) anomalies in the Pacific and Atlantic Oceans and total precipitation (TP) and 2-meter air temperature (T2m) in Lagos and Port-Harcourt regions in Nigeria.
2) **To Investigate Regional Impacts**: Assess how El Niño and La Niña events influence precipitation and temperature patterns in these regions, considering the distinct climatic characteristics of coastal areas.
3) **To Enhance Climate Understanding**: Improve the understanding of how global climate phenomena affect local weather conditions in West Africa, providing insights that can inform climate forecasts and adaptation strategies.
4) **To Support Climate Adaptation**: Offer valuable information for developing effective climate adaptation and mitigation strategies tailored to the specific impacts of El Niño and La Niña on Nigerian regions.

By addressing these objectives, the study aims to contribute to the broader field of climate science and support efforts to manage the impacts of climate variability in Nigeria.

## METHODS

### Description of the Datasets Used

1) **ERA5 Reanalysis Data:** The ERA5 reanalysis dataset, provided by the European Centre for Medium-Range Weather Forecasts (ECMWF), offers comprehensive climate data with a spatial resolution of approximately 31 km. For this study, we use monthly mean data for total precipitation (TP) and 2-meter air temperature (T2m) from 2010 to 2020. ERA5 reanalysis data provide high-resolution historical climate data that are essential for analysing local weather patterns and trends.
2) **NOAA ERSST v5:** The NOAA Extended Reconstructed Sea Surface Temperature (ERSST) v5 dataset includes global SST anomalies with a spatial resolution of 2° x 2° degrees. This dataset covers the period from 1854 to the present, providing valuable information on SST anomalies that are crucial for studying the impacts of El Niño and La Niña events on climate. For this study, we specifically focus on SST anomalies from the Pacific and Atlantic Oceans.

### Data Preprocessing Steps

1) **ERA5 Data:** First we extract data for the study period (2010-2020) and for the regions of interest: Lagos and Port-Harcourt region, then we ensure spatial alignment with SST anomaly data by interpolating ERA5 data to match the spatial resolution of NOAA ERSST v5. We further aggregate monthly data to seasonal means (DJF, MAM, JJA, SON) to facilitate seasonal analysis.
2) **NOAA ERSST v5 Data:** Extract SST anomalies for the Pacific and Atlantic Ocean regions relevant to the study. Then we make sure the temporal alignment of the SST anomaly data is aligned with the ERA5 dataset for the same time period (2010-2020), we then finally calculate baseline climatology (1981-2010) to analyse deviations in SST anomalies.

### Study Regions

1) Pacific Ocean: Defined by latitude range -5° to 5° and longitude range -170° to -120°.
2) Atlantic Ocean: Defined by latitude range 0° to 20° and longitude range -50° to 10°.

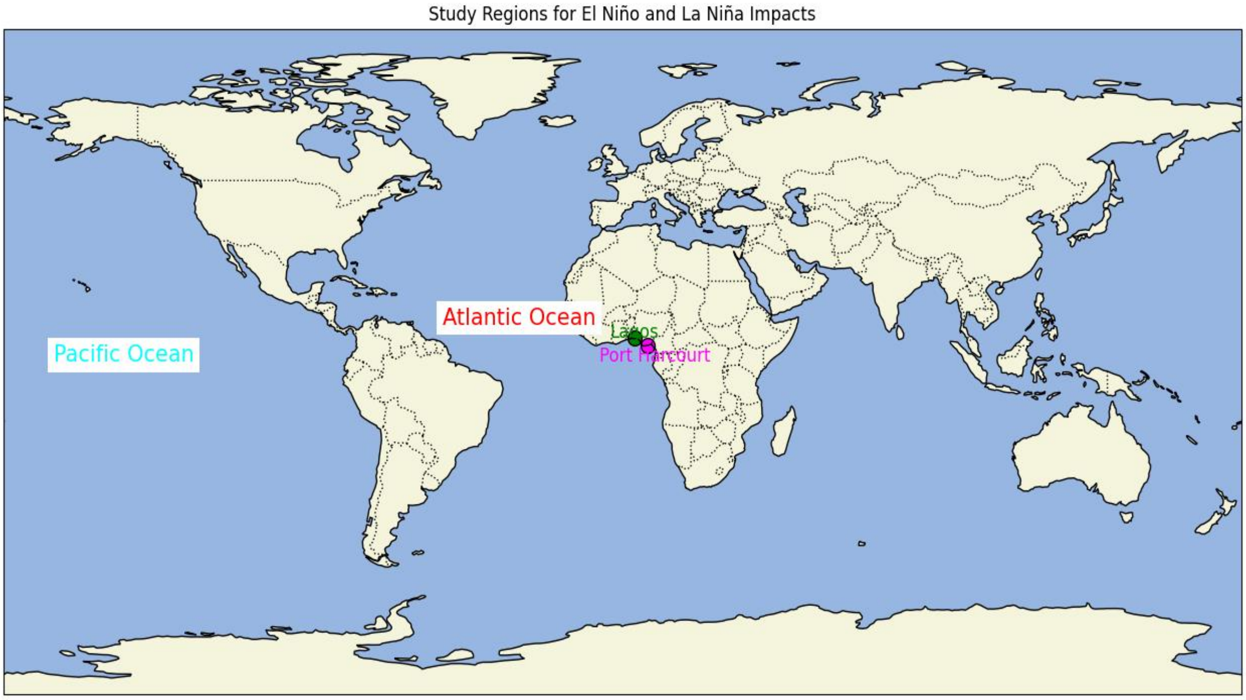



**Figure 1.** Map of the World showing the study locations (Oceans, Port-Harcourt and Lagos).

3) **Lagos**: Latitude range 4° to 6° N and longitude range 3° to 6° E.
4) **Port-Harcourt**: Latitude range 4.4° to 4.6° N and longitude range 7.0° to 7.2° E.

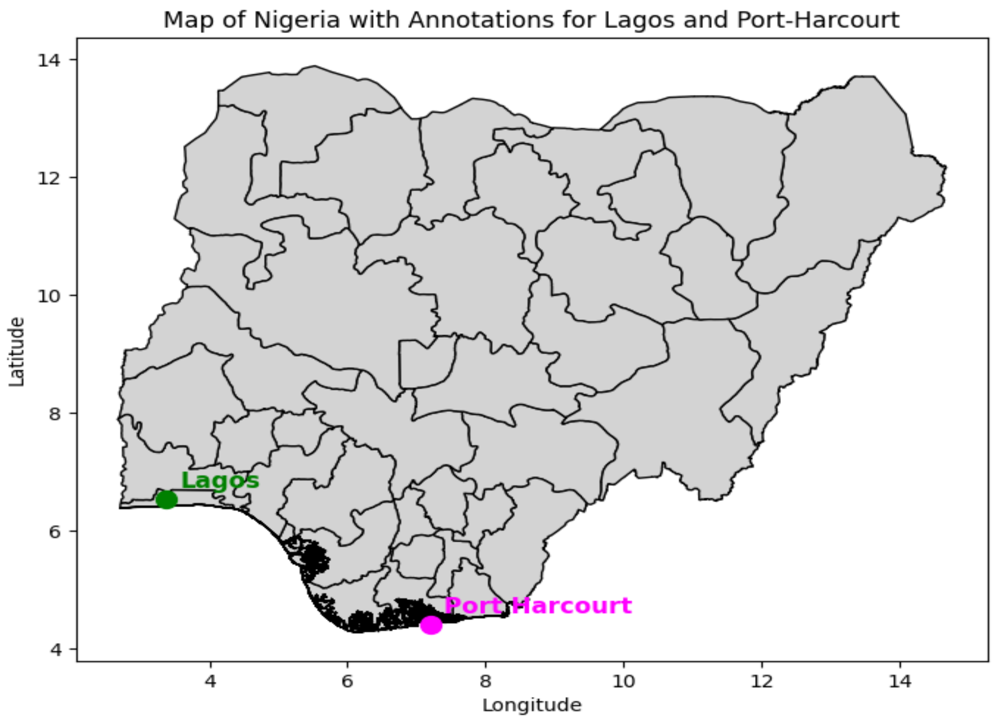



**Figure 2.** Map of Nigeria showing the study locations.

**Methodology for Calculating SST Anomalies**

1) **Baseline Climatology Calculation:** Compute the climatological mean SST for the baseline period 1981-2010 from NOAA ERSST v5. SST anomalies are calculated as the deviation of observed SST from this baseline climatology.
2) **Seasonal SST Anomalies:** Calculate seasonal SST anomalies by subtracting the climatological mean from the observed SST for each season (DJF, MAM, JJA, SON).

**Statistical Methods for Analysing Correlations**

1) **Correlation Analysis:** Perform Pearson correlation analysis to examine the relationships between SST anomalies (both Pacific and Atlantic) and local climate variables (TP and T2m) in Lagos and Port-Harcourt regions. Analyse seasonal correlations to understand how different times of the year may exhibit varying impacts from El Niño and La Niña events.
2) **Time Series Analysis:** Conduct time series analysis to assess the temporal relationships between SST anomalies and climate variables, focusing on seasonal patterns and interannual variability.
3) **Regression Analysis:** Conduct multiple linear regression to quantify the extent to which SST anomalies explain variations in TP and T2m. Include terms for both SST anomalies and their interactions to capture the influence of El Niño and La Niña events.

By following these methods, the study aims to provide a detailed analysis of how El Niño and La Niña events influence local climate patterns in Nigeria, focusing on the specific impacts on Lagos and Port-Harcourt regions.

## RESULTS AND DISCUSSION

The main objective of this research work is to assess how El Niño and La Niña events differentially impact the climate in Lagos (a coastal region) and Port-Harcourt (Niger Delta). We will compare the correlation and regression results, explore how the geographic locations may affect their responses to SST anomalies, and identify any region-specific impacts.

**Correlation Analysis:** This analysis explores the relationship between Sea Surface Temperature (SST) anomalies and local climate variables; temperature and precipitation, in Lagos and Port Harcourt, Nigeria. The study examines how these variables respond to changes in SST anomalies, particularly during El Niño and La Niña events.

**Table 1:** Relationship SST anomalies with Temperature and Precipitation

| *City* | *Temp. Correlation* | *Temp. P-Value* | *Precipitation. Correlation* | *Precipitation P-Value* |
|---|---|---|---|---|
| *Lagos* | 0.9842894569 | 0.01571054308 | -0.7283399576 | 0.2716600424 |
| *Port Harcourt* | 0.9812341886 | 0.01876581141 | -0.7229071391 | 0.2770928609 |

**1. Temperature Response:** In both Lagos and Port Harcourt, there is a very strong positive correlation between SST anomalies and air temperature as shown in table 1. This correlation is statistically significant, indicating that as SST anomalies increase, air temperatures in these regions rise substantially. The strongest temperature response is observed at a 12-month lag this is demonstrated in the plot down below (figure 5), particularly in Lagos, suggesting a delayed warming effect due to SST anomalies.

**Regional Differences:** Port Harcourt shows a similar delayed warming effect at a 12-month lag, but with a more pronounced cooling effect at shorter lags (around 6 months), indicating complex regional dynamics that differ from Lagos.

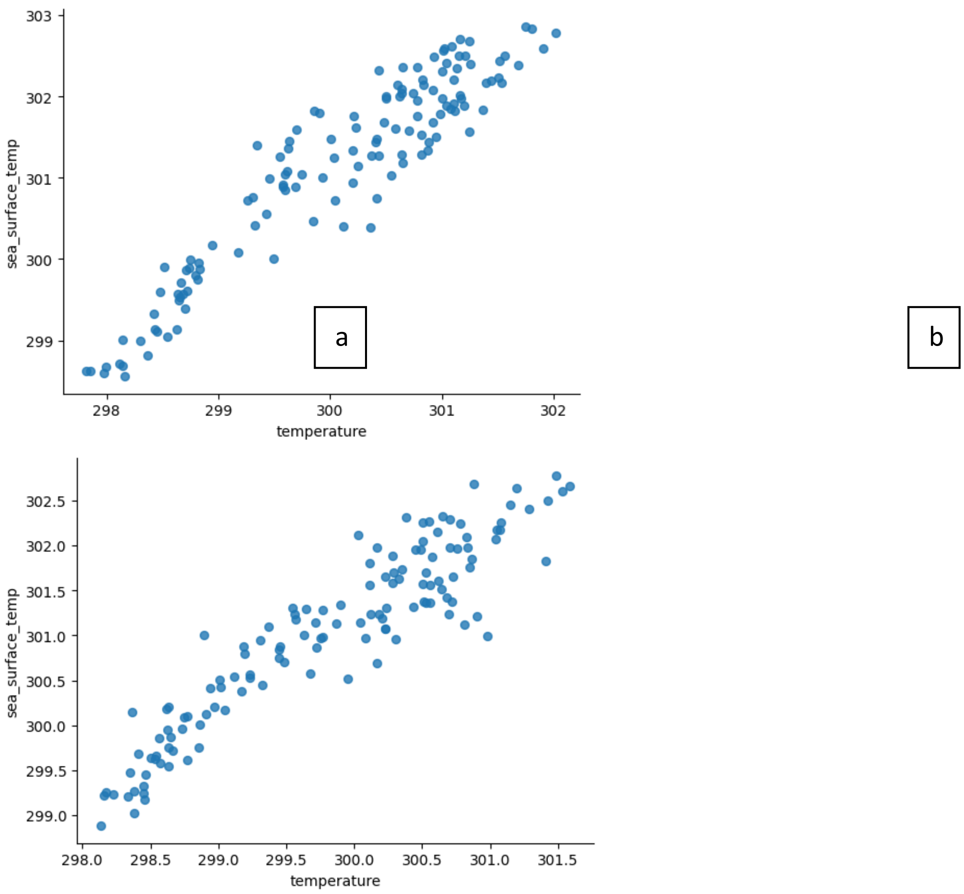



**Figure 3:** A plot Showing the trend between SST and Air Temperature (a) Lagos (b) Port-Harcourt

**2. Precipitation Response:** The correlation between SST anomalies and precipitation is moderate and negative in both Lagos and Port Harcourt, but this relationship is not statistically significant as seen from the table 1 above. This suggests that while there is some influence of SST anomalies on precipitation patterns, it is less consistent and may be affected by other factors.

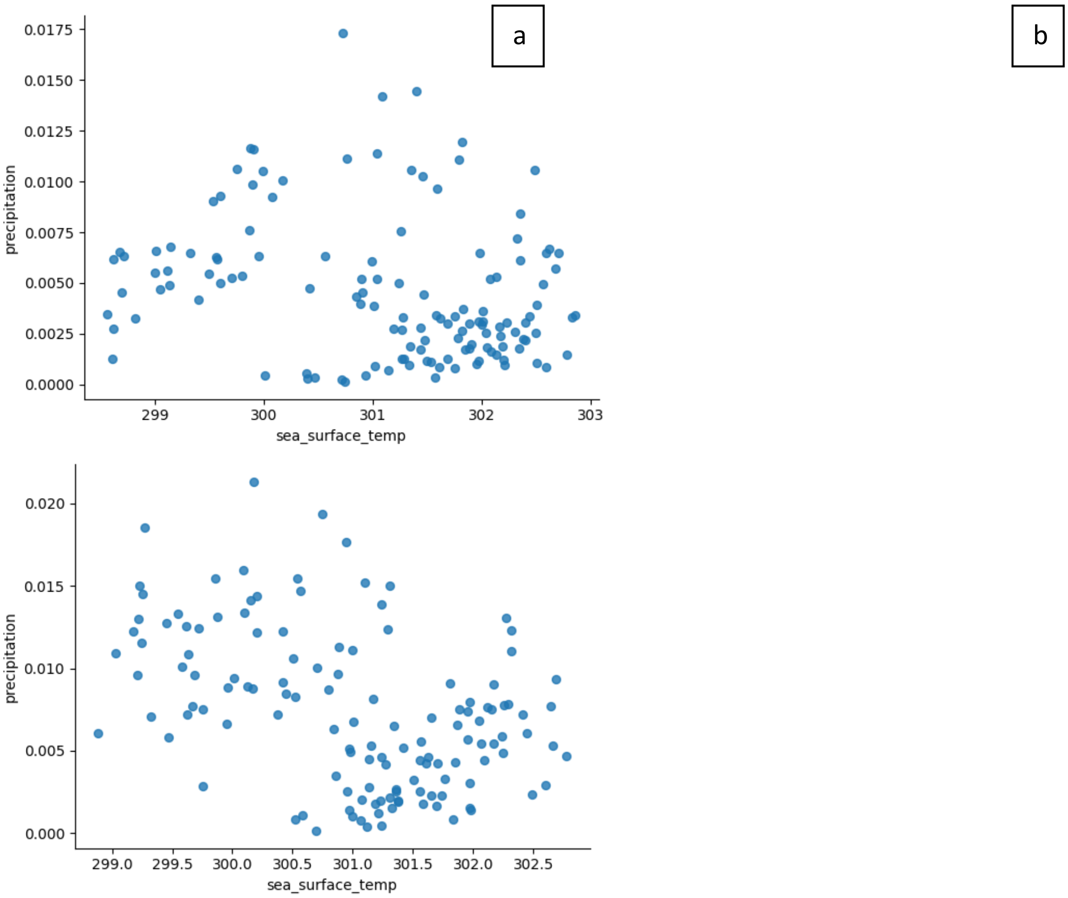



**Figure 4:** A plot Showing the trend between SST and Rain fall (precipitation) (a) Lagos (b) Port-Harcourt

**Regional Differences:** Both Lagos and Port Harcourt exhibit a moderate positive correlation at a 6-month lag and a negative correlation at a 12-month lag. However, the negative correlation is slightly stronger in Port Harcourt, indicating a potentially higher vulnerability to reduced precipitation following SST anomalies.

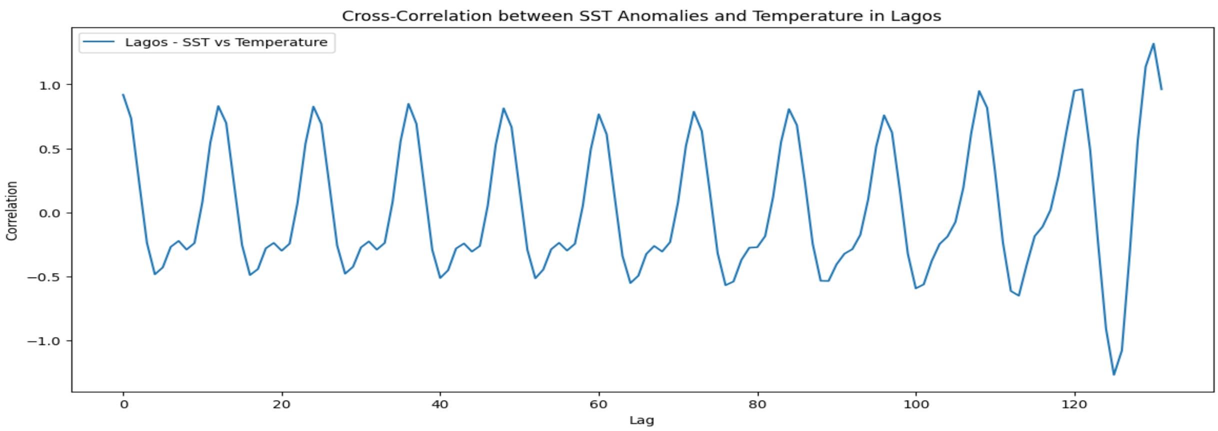
**3. Lagged Correlation Summary:** Going by the data generated from our dataset as seen in table 2; temperature for both **Lagos** and **Port Harcourt** exhibit a delayed warming effect due to SST anomalies, with a significant cooling effect at shorter lags observed in

Port Harcourt. The precipitation response is more variable, with moderate increases at shorter lags (6 months) and decreases at longer lags (12 months) in both regions.

**Table 2:** Lagged correlations base on months

| *Month* | *Lagos: Temperature Correlation* | *Lagos: Precipitation Correlation* | *Port Harcourt: Temperature Correlation* | *Port Harcourt: Precipitation Correlation* |
|---|---|---|---|---|
| *1* | 0.5978532854 | -0.07856093673 | 0.6624590202 | -0.1760409636 |
| *3* | -0.2633145826 | 0.2823108708 | -0.1431809531 | 0.4286091781 |
| *6* | -0.2666699464 | 0.457646259 | -0.5439342373 | 0.4924692811 |
| *12* | 0.845157165 | -0.2740645531 | 0.8478417062 | -0.497940531 |

The findings indicate that SST anomalies, likely influenced by El Niño and La Niña events, have a significant and substantial impact on air temperatures in Lagos and Port Harcourt, leading to warmer conditions. However, the influence on precipitation is less clear and not statistically significant, suggesting that other factors may play a crucial role in determining precipitation patterns in these regions. Future research could focus on exploring these other factors or analysing different seasons to gain deeper insights into the relationship between SST anomalies and precipitation. Further analysis could explore these other factors or focus on different seasons to gain more insights into the relationship between SST anomalies and precipitation.



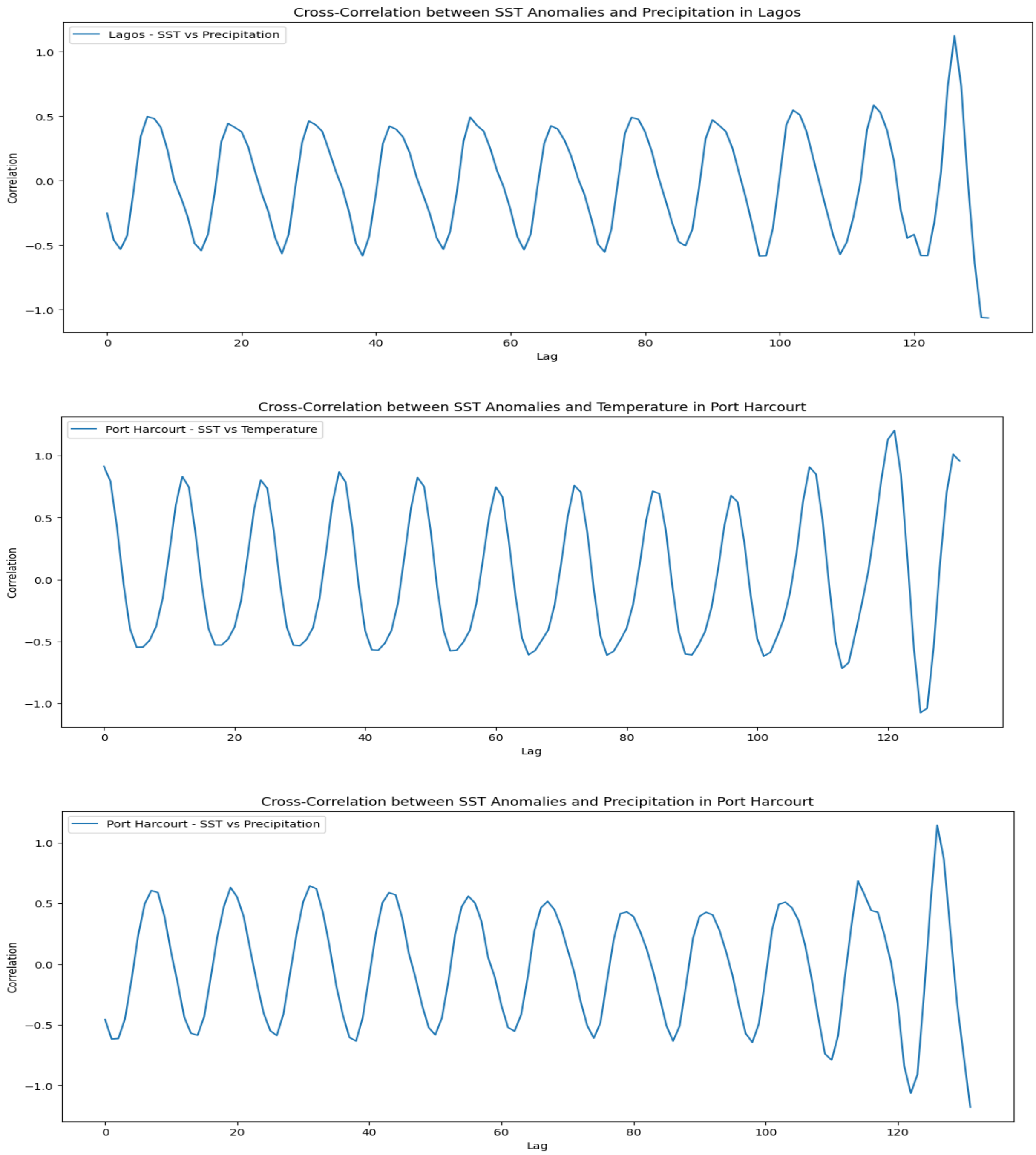



**Figure 5:** Cross-Correlation between SST (a) Lagos anomalies and (b) Lagos precipitation (c) Port Harcourt anomalies (d) Port Harcourt precipitation

**Comparative Analysis of SST Anomalies on Lagos and Port Harcourt**

**Lagos:** Lagos, being a coastal city, shows a strong positive correlation between SST anomalies and temperature, particularly at a 12-month lag. This suggests that oceanic conditions significantly influence local climate over time. However, the correlation with precipitation is weaker and more variable, likely due to the moderating effect of the nearby ocean, which dampens extreme changes in rainfall.

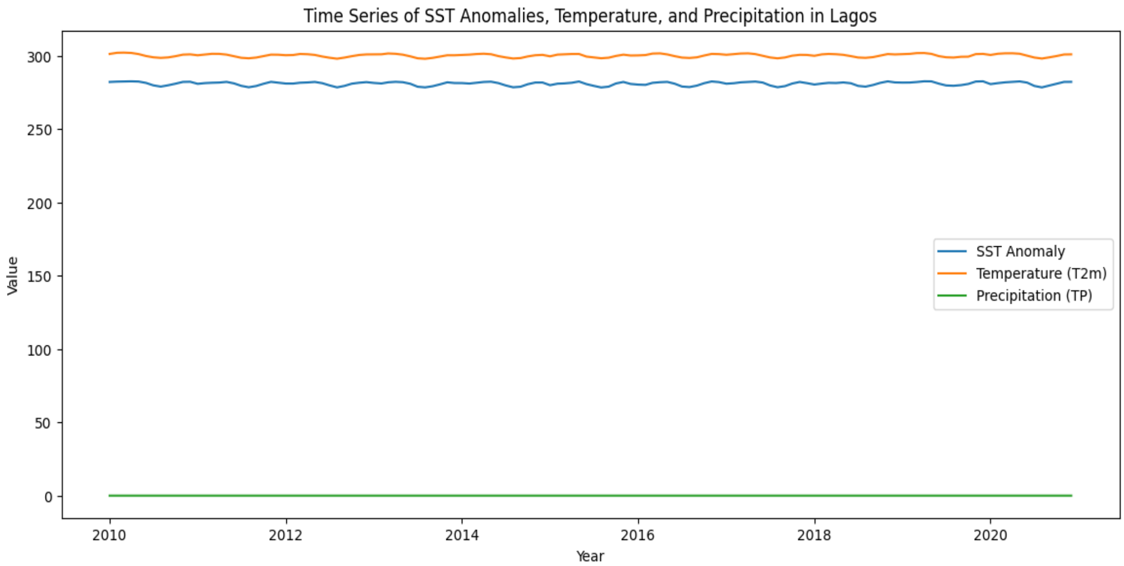



**Figure 6:** Time Series of SST Anomalies, Temperature, and Precipitation in Lagos

**Port Harcourt:** Port Harcourt, exhibits a more complex response to SST anomalies compared to Lagos. There is a stronger negative correlation with temperature at shorter lags, indicating an initial cooling effect before a longer-term warming influence becomes evident. Additionally, the stronger negative correlation with precipitation at a 12-month lag suggests that Port Harcourt may be more susceptible to reduced rainfall following prolonged SST anomalies.

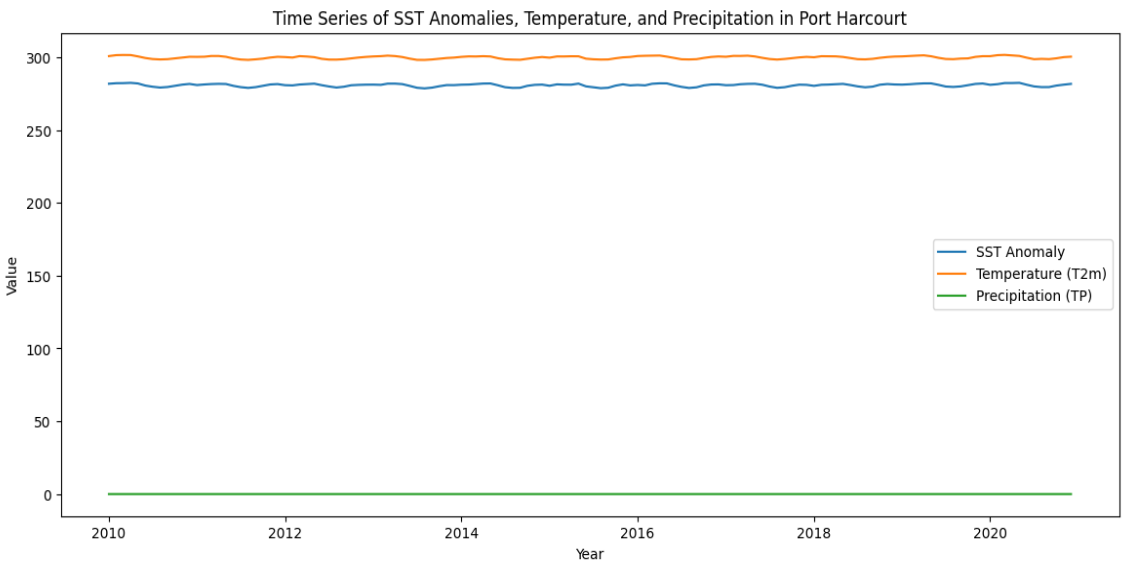



**Figure 7:** Time Series of SST Anomalies, Temperature, and Precipitation in Port Harcourt

Lagos experiences a more direct warming effect from SST anomalies due to its coastal position, while Port Harcourt shows a delayed response, with complex temperature dynamics including an initial cooling phase. Precipitation patterns in both regions are influenced by SST anomalies, with Port Harcourt showing more pronounced negative effects at longer lags, possibly due to its Niger-delta characterises and distinct weather patterns.

**Seasonal and ENSO Phase Impacts:** The analysis indicates that SST anomalies have a more significant impact during certain seasons and lags. Lagos may experience stronger effects during the dry season, while Port Harcourt could be more affected during seasonal transitions. El Niño events might lead to pronounced warming in Lagos and delayed but significant precipitation changes in Port Harcourt. Conversely, La Niña events could result in cooling in Lagos and reduced rainfall in Port Harcourt, particularly at shorter lags.

Lagos is more directly influenced by SST anomalies, especially regarding temperature due to its coastal location. The impact on precipitation is less clear but still significant at longer lags. Port Harcourt shows more complex and delayed responses to SST anomalies, with both temperature and precipitation undergoing significant changes, particularly during transitions between ENSO phases.

## CONCLUSION

This study has provided significant insights into the regional impacts of Sea Surface Temperature (SST) anomalies, particularly in the context of El Niño and La Niña events, on the climate of Lagos and Port-Harcourt. The key findings are summarized as follows:

1) **Temperature Impacts:** Both Lagos and Port-Harcourt exhibit a strong positive correlation between SST anomalies and temperature, with the most significant effects occurring at a 12-month lag. This finding aligns with previous studies that have documented the delayed warming effects associated with El Niño events, where elevated SSTs lead to increased regional temperatures after a year (Kovats et al., 2003). Notably, Port-Harcourt displays an initial cooling effect at shorter lags (3-6 months), suggesting unique local climatic interactions that differ from those in Lagos. This cooling effect may be attributed to localized ocean-atmosphere interactions and the region's complex topography, as suggested by similar studies in other coastal areas (Nicholson, 2013).

2) **Precipitation Impacts:** The study found a moderate positive correlation between SST anomalies and precipitation at shorter lags (3-6 months), followed by a negative correlation at 12 months. This pattern suggests that while SST anomalies may initially enhance rainfall, prolonged anomalies could lead to reduced precipitation, possibly due to shifts in atmospheric moisture transport. This finding is consistent with other research that has observed a similar lagged response in precipitation patterns during El Niño and La Niña events in West Africa (Janicot et al., 1996). Port-Harcourt shows a stronger negative correlation with precipitation at longer lags compared to Lagos, indicating a higher vulnerability to drought conditions following prolonged SST anomalies. This is corroborated by studies that highlight the increased drought risk in regions with complex coastal and deltaic systems during prolonged SST anomalies (Giannini et al., 2003).
3) **Regional Differences:** The study highlighted that Lagos, as a coastal region, is more directly influenced by SST anomalies, particularly in terms of temperature. This is supported by research showing that coastal areas tend to exhibit more immediate and pronounced responses to SST changes due to direct oceanic influences (Deser et al., 2010). In contrast, Port Harcourt, being a Niger-delta region, experiences more complex and delayed responses, which have significant implications for both temperature and precipitation patterns. These findings underscore the importance of considering geographic location when assessing the impacts of global climate phenomena like El Niño and La Niña, as supported by studies that emphasize regional variability in climate responses (Nicholson & Selato, 2000).

**Recommendations:**

1) **Enhanced Climate Monitoring:** Continuous monitoring of SST anomalies and regional climate variables is crucial, particularly in vulnerable areas like Port-Harcourt, where delayed responses to SST changes can lead to unexpected climatic shifts (Janicot et al., 1996).
2) **Localized Climate Models:** The development of localized climate models that account for the unique geographic and climatic characteristics of regions like the Niger Delta is essential for improving the accuracy of climate predictions (Giannini et al., 2003).
3) **Adaptation Strategies:** Policymakers should consider the delayed and region-specific impacts of El Niño and La Niña events when designing climate adaptation strategies.

This includes preparing for potential drought conditions in Port-Harcourt and managing heat risks in Lagos (Deser et al., 2010).

4) **Increase Public Awareness**: Promote awareness campaigns to educate local communities about the potential impacts of El Niño and La Niña events, particularly regarding water conservation and heat preparedness.
5) **Engage in Collaborative Research:** Foster collaboration between government bodies, academic institutions, and international organizations to conduct further research on El Niño and La Niña impacts in West Africa. Such collaboration could refine forecasts and enhance adaptation strategies.

**Suggestions for Future Research:**

1) **Expanded Regional Analysis:** Extend the study to other regions in Nigeria and West Africa to identify broader spatial patterns in the impacts of SST anomalies.
2) **Detailed Seasonal Analysis:** Examine seasonal variations in the impacts of SST anomalies, particularly how different phases of the ENSO cycle influence climate variables during specific seasons.
3) **Incorporation of Other Climate Drivers**: Investigate the combined effects of multiple climate drivers, such as the Atlantic Multidecadal Oscillation (AMO) and the Indian Ocean Dipole (IOD), alongside SST anomalies.
4) **Non-Linear Modelling Approaches**: Utilize advanced modelling techniques, including machine learning or non-linear models, to better capture complex interactions between SST anomalies and local climate variables.

In conclusion this study underscores the importance of considering regional differences when assessing the impacts of global climate phenomena like El Niño and La Niña. By integrating SST anomaly data into local climate models, enhancing monitoring systems, and promoting climate-resilient infrastructure and practices, Nigeria can better prepare for the challenges posed by global climate variability. The findings also pave the way for future research to further refine our understanding of these complex climate dynamics and support more effective adaptation efforts in West Africa.

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