J. Chosun Natural Sci.
Vol. 13, No. 1 (2020) pp. 27 – 33
https://doi.org/10.13160/ricns.2020.13.1.27

A Study at Investigating the Climate Change in East Asia with Changing Sea Surface Temperature

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Abstract

The unsustainable human activities like increased use of automobiles, heavy industrialization and the use of large volumes of fertilizers, chemicals and pesticides in the agricultural land cause climate change problems in one way or another. Under normal circumstances, the heat radiations from the sun will be reflected back. An excessive volume of GHGs in the atmosphere would prevent these radiations from reflecting back. East Asia is facing severe climate change issues in recent times. A lot of climate change problems such as hurricanes and floods have been reported from this region in the last couple of decades. The study aimed at investigating the climate change in East Asia with changing Sea Surface Temperature (SST). The study adopted a quantitative research method with a case study research design where a deliberate focus was made on the East Asia Region. Secondary data was gathered and analyzed to yield both descriptive and inferential statistics. The study concluded that the impact of East Asia Climate variability was significant mainly for some extreme events. Also, the study concluded that there was a significant link between the change of the East Asia climate variability and that of the sea surface temperature. Further, the study concluded that a linear relationship existed between the sea surface temperature and the climate of East Asia. Hence, a linear regression was a significant predictor of the East Asia Climate (EAC) based on changing sea surface temperature. The model revealed that 37.4% of the variations in the climate change index were explained by the changes in the sea surface temperature. The climate was expected to change with a value of 49.48 for a unit change in the sea surface temperature.

Keywords : Climate Change, GHG, EAC, SST, Descriptive and Inferential Statistics

1. Introduction

With the inevitable changes in climatic conditions, countries and their populations' have no option but to adapt to higher temperatures and changed patterns of precipitation. Changes have been made globally, particularly in sectors such as agriculture and business, in the bid to adapt to changes in climate and the related market signals. The climate of East Asia is cold and temperate. A comparison between winter and summers revealed that more rainfall is experienced in summer than in winter[1]. The climate classification by Koppen-Geiger is Dwa with annual temperature averaging at of 12.1°C and an annual rainfall averaging at 610 mm[2]. As noted by Choi et al. and as seen in Fig. 1 surface air temperature (SAT) and sea surface temperature (SST) around East Asia are varying drastically in recent years because of global warming problems[3]. For example, the study by Weller et al., [4] proved that the intensity of typhoon is getting stronger in recent years around the Western Pacific because of the increase in sea surface temperature (SST). Moreover, the warm pool near the Indian Ocean and the Pacific is expanding more and more resulting in increased typhoon routes to East Asia and Southeast Asia. The intensity of typhoons in countries such as China, Taiwan, Japan, Korea, and the Philippines is directly proportional to the SST around the Korean peninsula (Ray et al., 2018).

In other words, the frequency of occurrence and the strength of typhoons in these countries increase when SST around the Korean peninsula increases and vice versa.

According to a study by Joydeep Gupta[1], most of the East Asian countries may experience 50% more rainfall in coming years because of climate change. At the same

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(Received : February 20, 2020, Revised : March 10, 2020, Accepted : March 14, 2020)

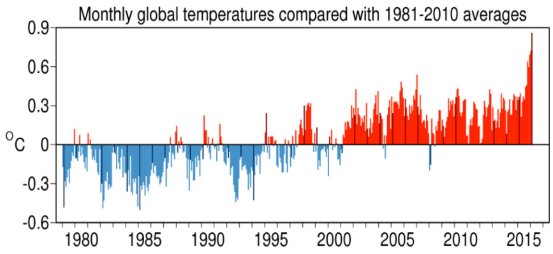

Fig. 1. Monthly global-mean surface air temperature anomalies relative to the monthly averages for 1981-2010 (Adapted from Climate.copernicus.eu).

time, some of the East Asian countries like Pakistan and Afghanistan may experience a decline in rainfall by 20-50%[1]. In other words, climate change problems may affect different East Asian countries in a different manner in the coming years. For example, countries such as India have faced massive floods and hurricanes in August 2018. Kerala, the southernmost state of India has witnessed a massive flood in 2018. The strange thing is that the state has experienced it again in 2019 and that also in the same month August itself. According to Shaji, the state is slowly becoming a major victim of climate change[5].

Although the southern regions of India have faced massive floods during monsoon seasons in recent years, the northern regions are comparatively free from the dangers of floods. It should be noted that the northern regions of India were flood-prone areas in India in the past. However, the southern regions facing more problems in recent times because of climate change.

1.1. Problem Statement

One of the major problems everywhere in the world at present is that of climate change. No country or continent is free from the effects of global warming or climate change problems. If the atmospheric temperature goes on increasing at the present rate, the sustainability of life on earth could be in big danger in the near future itself. There were plenty of theories regarding the cause of climate change problems. Some people believe that climate change is a naturally occurring process and human has no role in causing this problem. On the other hand, plenty of others believe that human plays a major role in causing climate changes in this world.

The unsustainable human activities like increased use of automobiles, heavy industrialization and the use of large volumes of fertilizers, chemicals and pesticides in the agricultural land cause climate change problems in one way or another. Under normal circumstances, the heat radiations from the sun will be reflected back. However, an excessive volume of GHGs in the atmosphere would prevent these radiations from reflecting back. East Asia is facing severe climate change issues in recent times. A lot of climate change problems such as hurricanes and floods have been reported from this region in the last couple of decades. The geography and demography of East Asia made it one of the most vulnerable regions in the world in terms of climate change. For example, the Koran Peninsula, which is a region in East Asia, is greatly affected severely by climate change problems. As in the case of many other East Asian countries, the Korean peninsula faces severe problems such as floods, hurricanes, landslides, and droughts because of global warming and subsequent climate changes in the region.

The impact of climate change on the growth and yields of agricultural crops is more visible in the Korean peninsula compared to that in other regions of East Asia. For example, forsythias, azaleas, and oriental cherry, the three major tree species in Korea bloomed six to eight days earlier than expected for the past 30 years[1]. Such changes in the blooming will affect the quality of crops and fruits yielded from the Korean peninsula region. Claims have been made that the idea on how to adjust to the changing climate can be well developed with the understanding of the relationship between changes in the climate and the changing sea surface temperature (SST). It is therefore, important to conduct a research that establishes a link between climate change in the East Asia and the changing Sea Surface Temperature (SST).

1.2. Research Objective

The study aimed at investigating the climate change in East Asia with changing Sea Surface Temperature (SST). The study has three specific objectives as follows : 1) To investigate the mechanisms and impacts of East Asia Climate (EAC) variability, especially for some extreme events. 2) To assess the change of the East Asia Climate variability with changing sea surface temperature. 3) To develop a model for predicting the East Asia Climate (EAC) based on changing sea surface temperature.

2. Methodology

2.1. Research Method and Design

The study adopted a quantitative research method. The method entailed gathering numerical data, analyzing them using mathematical models and techniques, and drawing conclusions based on the analysis results. The method was advantageous because it enabled the analysis of large amounts of data for better generalization of the results. Also, the method allowed the use of modern statistical tools for data analysis, easing the processes of data analysis. Through the quantitative approach, the study was able to use standard procedures, enabling a comparison of the results with those from studies done in the past or from other regions.

2.2. Study Area

The study was based in East Asia. East Asia is an area located in the Southeast part of the Eurasian continent bordering the Pacific Ocean to the east and Tibetan Plateau (TP) to the southwest[3]. The unique geographical feature in the area produces distinct climate characteristics making studies done on EAC the foci of the Asian Monsoon Years (AMY 2007-2012), a coordinated observation and modeling effort under the leadership of the World Climate Research Program.

2.3. Data Collection

The study used data from secondary sources. Hence, secondary data was used. Secondary data refers to data that is collected by someone other than the user. The choice for secondary data was made following the economic nature of the data. According to Arroyuelo, Oyarzún, González, & Sepulveda[6], the secondary data collection process saves efforts and expenses significantly in addition to saving time.

Fig. 3. East Asia map.

The study gathered time-series data for a period of at least 30 years. A time series is a series of data points indexed in time order[7]. For this particular study, the time series presented a sequence taken at successive equally spaced points in time with intervals of one year. The data was organized into two broad categories, namely the dependent and independent variables. The independent variables included all facts gathered about sea surface temperatures (SST), while the dependent variables included all facts gathered regarding the climatic conditions of East Asia. The major climatic indicators included the maximum temperatures, humidity, wind speed, and precipitation[8]. The overall climate change index was for a particular period was a derived variable obtained after adding all the scores for the four climate indicators.

2.4. Data Analysis

The study used descriptive analysis, time series analysis, and inferential analysis techniques. The descriptive statistics analysis entailed the computation of measures of central tendency and dispersion. On the other hand,

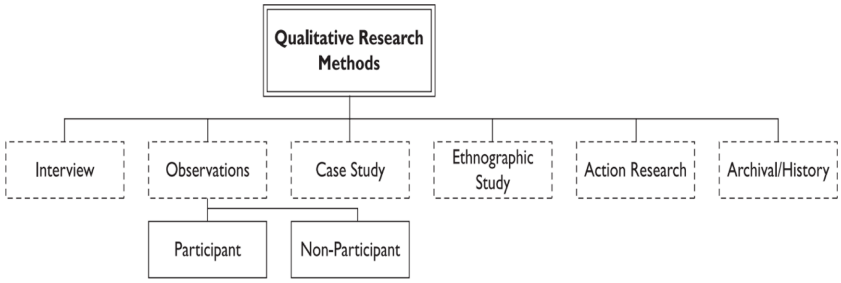

Fig. 2. Quantitative research methods diagram.

time series analysis entailed the description of the climatic and sea surface temperature trends over time. Conversely, the inferential statistics involved time series forecasting using models for predicting future values based on previously observed values. In particular, the study relied on a linear regression model with climate change in East Asia as the dependent variable and sea surface temperature (SST) as the independent variable. The model assumed the form shown below (Zhang, 2016).

$$y = \beta_0 + \beta_1 x + \varepsilon_{ij}$$

Where; y was the climate change index in East Asia and x the sea surface temperature (SST). The betas represented the model parameters while the epsilon sign represented the error term associated with ith and jth observations of the climatic score and sea surface temperature (SST), respectively.

Discussions

3.1. The Mechanisms and Impacts of East Asia Climate (EAC) Variability, Especially for Some Extreme Events

The study assessed the variability of the East Asia Climate using descriptive analysis techniques. The maximum temperatures recorded in the East Asia region averaged at 29°C with a standard deviation of 1.24. The humidity averaged at 78.17% with a standard deviation of 2.26 while the wind speed averaged at 2.34 m/s with a standard deviation of 0.145. The fourth variable used to measure the climate of East Asia region was precipitation, which averaged at 392.02 mm with a standard deviation of 61.177. The values of standard deviations revealed that the variables describing the climate of the area under investigation varied. The variations meant that the overall climate of the area was changing with time. These variations were linked to the local and regional differences, which influenced the climatic conditions. Also, the time of the day that the data was recorded would have caused some minor variations in the sea surface temperatures. On the other hand, the study observed that the sea surface temperature (SST) averaged at 27.290C with a standard deviation of 0.778. Again, there were notable changes in the sea surface temperature over time. The descriptive statistics triggered the need for a further association assessment to investigate whether the observed changes in the climatic conditions were related to the changes in the sea surface temperature (SST). The extreme temperatures were observed in the year 2013 with a maximum value of 32.20C. The temperature was associated with the considerable heating up of the surface during hot summers, an event which caused a low-pressure area over the northern and central parts of Asia[9]. As a result, extreme figures were observed for the wind speed at the same time, where a low value of 2.1 m/s was recorded. It was argued that the pressure difference reduced lowering the speed of the wind.

Table 1. Descriptive analysis results

Statistics	Maximum temperature	Humidity	wind speed (M/s)	Precipitation	Climatic score	Sea surface temperature (SST)
Means	29	78.16667	2.336667	392.0233	501.5267	27.28667
Standard errors	0.244291	0.412682	0.026472	11.16952	11.49011	0.142049
Median values	29	78	2.3	391.8	503.45	27.3
Standard deviations	1.338038	2.260353	0.144993	61.17799	62.93392	0.778032
Sample variances	1.790345	5.109195	0.021023	3742.746	3960.678	0.605333
Kurtosis values	0.102257	-0.86332	-0.79893	-0.47288	-0.50067	-0.2149
Skewness values	0.720672	0.085666	0.320684	0.260796	0.286422	0.061836
Range values	4.9	8	0.5	236.4	242.2	3.1
Minimums	27.3	74	2.1	285.9	394.4	25.8
Maximums	32.2	82	2.6	522.3	636.6	28.9
Sums	870	2345	70.1	11760.7	15045.8	818.6
Counts	30	30	30	30	30	30

3.2. The Change of the East Asia Climate Variability with Changing Sea Surface Temperature

The link between the change of the East Asia climate variability and that of the sea surface temperature was investigated using the correlation analysis technique. The analysis produced a correlation coefficient equal to 0.612. The value was neither too close to zero nor to 1, implying that the association was moderate. Also, the value was positive, indicating that the association was positive. A conclusion was made that a rise in the sea surface temperature was associated with a moderate change in the climate of East Asia.

Graphical representation of the association between the East Asia Climate variability and sea surface temperature was done using a scatter plot diagram. The diagram revealed that an upward trend existed in the long run, although minor trends were present in the short run. Nonetheless, the R-value was significant, indicating that the linear trend was identifiable.

3.3. A Model for Predicting the East Asia Climate (EAC) Based on Changing Sea Surface Temperature

The study developed a model for predicting the East Asia Climate (EAC) based on changing sea surface temperature with the help of a linear regression analysis technique. The results of the regression statistics yielded

Table 2. Descriptive analysis results

*C*lassify	SeaSurface Temperature (SST)	Climate change index
SeaSurfaceTemperature	1	
Climate change index	0.611709	1

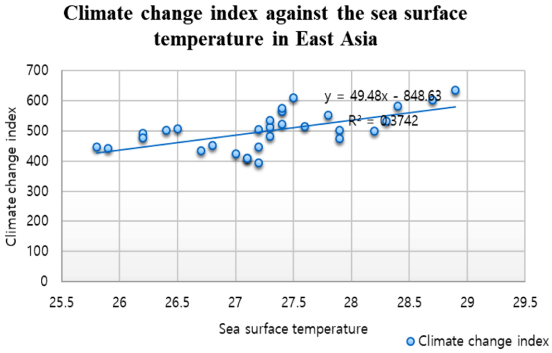

Fig. 4. Association between the East Asia Climate variability and sea surface temperature.

Table 3. Summary of regression model statistics

Regression statistics	
Multiple R value	0.611709
R Squared value	0.374188
Adjusted R Squared	0.351838
Standard E	50.66716
Counts	30

values equal to 0.6117 and 0.374 for the multiple R and R-square values, respectively. The value of Multiple R, just the correlation coefficient presented in the previous sub-section, described the association between the East Asia climate (EAC) and the sea surface temperature. The results indicated that the association was moderate and positive. Hence, a rise in the sea surface temperature was associated with a rise in the climate change index. On the other hand, the value of R-square presented the coefficient of multiple determinations. This value implied that 37.4% of the variations in the climate change index were explained by the changes in the sea surface temperature.

The significance of the model for predicting the East Asia Climate (EAC) based on changing sea surface temperature was tested using the Analysis of Variance (ANOVA) technique. The computed value of the F statistic was equal to F=16.74, with a significance value of 0.0003<0.05. The results were statistically significant, indicating that the model fit was good.

The model parameters and their significance were investigated using the analysis of the coefficients. The study obtained values equal to -0.848.627 and 49.48 for the model intercept and the coefficient of the sea surface temperature, respectively. The values implied that the model for predicting the East Asia Climate (EAC) based on changing sea surface temperature was of the form;

$$y = -848.627 + 49.48x$$

Where; y was the climate change index in East Asia and x the sea surface temperature (SST).

The model suggested that the climate was expected to change with a value of 49.48 for a unit change in the sea surface temperature. The probability value for the coefficient of sea surface temperature was less than 0.05, indicating that the prediction ability of the model was significant.

Table 4. ANOVA results

	D f	S S	M S	F-value	Significance value
Regression values	1	42979.14	42979.14	16.74189	0.000328
Residual statistics	28	71880.52	2567.161		
Total	29	114859.7			

Table 5. Model coefficients analysis results

	Coefficients	Std Error	t-Stats	Probability-value
Intercept value	-848.627	330.1044	-2.57078	0.015753
Sea Surface Temperature (SST)	49.48033	12.0929	4.091686	0.000328

Conclusions

The study concluded that the impact of East Asia Climate variability was significant mainly for some extreme events. The variations observed in the temperatures, humidity, wind speed, and precipitation meant that the overall climate of the area was changing with time. These variations were linked to the local and regional differences, which influenced the climatic conditions. Also, the time of the day that the data was recorded would have caused some minor variations in the sea surface temperatures. Similarly, the study observed that the sea surface temperature (SST) averaged at 27.290C with a standard deviation of 0.778. Again, there were notable changes in the sea surface temperature over time.

Also, the study concluded that there was a significant link between the change of the East Asia climate variability and that of the sea surface temperature. The analysis produced a correlation coefficient equal to 0.612, implying that there was a moderate and positive association between the change of the East Asia Climate variability and changing sea surface temperature. The association led to the conclusion was made that a rise in the sea surface triggered a moderate change in the climate of East Asia.

Further, the study concluded that a linear relationship existed between the sea surface temperature and the climate of East Asia. Hence, a linear regression was a significant predictor of the East Asia Climate (EAC) based on changing sea surface temperature. The model, through the coefficient of multiple determinations, revealed that 37.4% of the variations in the climate change index were explained by the changes in the sea surface temperature. In particular, the model coefficients suggested that the climate was expected to change with a value of 49.48 for a unit change in the sea surface temperature.

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