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Trend Analysis of Maximum and Minimum Temperature in Can Tho City, Viet Nam

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Abstract: Can Tho City is located in the middle of the Mekong Delta, where the effects of climate change have been and will continue to be considerable. According to climate change predictions, the city is one of five regions that could be affected. In this study, we conducted analysis of trends of T_{max} and T_{min} over 39 years using monthly temperature in Can Tho City. We employed a Box plot, Mann–Kendall test, and Sequential Trend Analysis (SMK). T_{max} and T_{min} increased for all 12 months from 1984 to 2022, with Sen's slopes of 0.45°C/decade and 0.29°C/decade, respectively. Although T_{min} shows a slower rate of increase than T_{max}, the increase in T_{min} indicates that the temperature in Can Tho has risen.

Keywords: The maximum temperature; The minimum temperature; Mann-Kendal test; Sequential trend analysis.

Introduction

Climate change and natural disasters have a particularly high impact on Vietnam. For example, Vietnam was affected by storms and floods were the most frequent catastrophic natural catastrophes. Every year, extreme disasters had a negative effect on Vietnam's ecology, habitat, and social development (Nguyen et al., 2017; IPCC, 2013). Therefore, climate change caused changes in the water cycle, increased surface temperatures and extreme drought as well as extremely wet occurring (Nguyen et al., 2017; Minh et al., 2022).

In Vietnam, there are 187 surface meteorological monitoring stations since 2020. However, the assessment of climate change manifestation can only be done with monitoring stations that have been in operation since 1986 and have collected data for at least 30 years. According to the updated Climate Change Scenario 2020, DONRes (2020) found that the climate change indicators in Vietnam: temperatures tended to rise between 1958 and 2018 based on historical data of Vietnamese monitoring stations. The average annual temperature rises at a pace of roughly 0.15°C every decade. The annual rainfall was shown to be decreasing in the northern parts (from 5% to 10%/61 years) and increasing in the southern regions (from 5 to 15%/61 years) (Nguyen et al., 2017).

From 2005 to 2016, global surface temperature increased by 0.87°C (0.76–0.98°C) compared to the pre-industrial period (1850–1900). The current decade (2009-2018) saw an even faster growth, reaching 1.06°C (0.95–17°C). Since 1975, the average global

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surface temperature has grown by 0.15–0.2°C every decade. Global surface temperature has been recorded as the highest in the recent four decades, dating back to 1850 and continuing today. The observed global average rainfall from 1980 to 2018 rose quicker than from 1901 to 2018. Droughts vary widely on a worldwide scale, but they are getting more severe and long-lasting (Nguyen et al., 2017). In Vietnam, the average annual temperature has been rising over the past few decades, but it has increased most quickly in the last ten years (2011–2018), particularly in the past few years, which are thought to have had high national average temperatures. In Vietnam, records of the highest temperature have been kept by more than 30% of stations since 1958 (DONRes, 2020).

A large number of studies related to hydrology and meteorological assessment have been conducted in Viet Nam and Can Tho City (Nguyen et al., 2017; Thoảng et al., 2020; Lavane et al., 2023; Minh et al., 2022; Ty et al., 2022. Droughts may develop gradually and last for extended periods of time. The World Meteorological Organization advises using the Standardized Precipitation Index (SPI) as well as climate change prediction (Van Ty et al., 2023). The impact of climate change on drought and water resources was also conducted (Minh et al., 2022; Ty et al., 2015). Since the city is located in the middle of the Mekong Delta, where the effects of climate change have been and will continue to be considerable. According to climate change predictions, the city is one of five regions that could be affected. Climate change has had the greatest impact on those affected. Can Tho city show specific signs of climate change. Can Tho is less vulnerable to storms and seawater intrusion because it is situated in the Mekong Delta's interior zone. Nonetheless, the City's living conditions have been impacted by changes in the environment over time. A thorough local assessment of the highest and lowest temperatures is required, taking into account the particular degree of urban warming. The findings serve as the empirical foundation for further study.

Methodology

A. Study Area and Data Collection

Can Tho is situated in the middle and lower reaches of the Mekong Delta, covering 65 kilometers along the west bank of the Hau River (Figure 1). The city's total natural area is 1,401.61 km^2, which accounts for 3.49% of the region's total area. Can Tho is located in the Mekong Delta climate zone, which has common characteristics such as high and steady temperatures, small day and night temperature amplitudes, and two distinct seasons: wet and dry. The wet season lasts from May to October, while the dry season runs from November to April the next year. The average maximum temperature is 31.7^{o}C (1984–2022), and the average minimum temperature is 24.3°C (1984–2022). Average annual rainfall in Can Tho is 1,624 mm (1978–2022), on which wet season rainfall is 1,492 mm (from V to XII, accounting for 92%) with dry season rainfall is 132 mm (XII to IV of the following year, account for 8%).

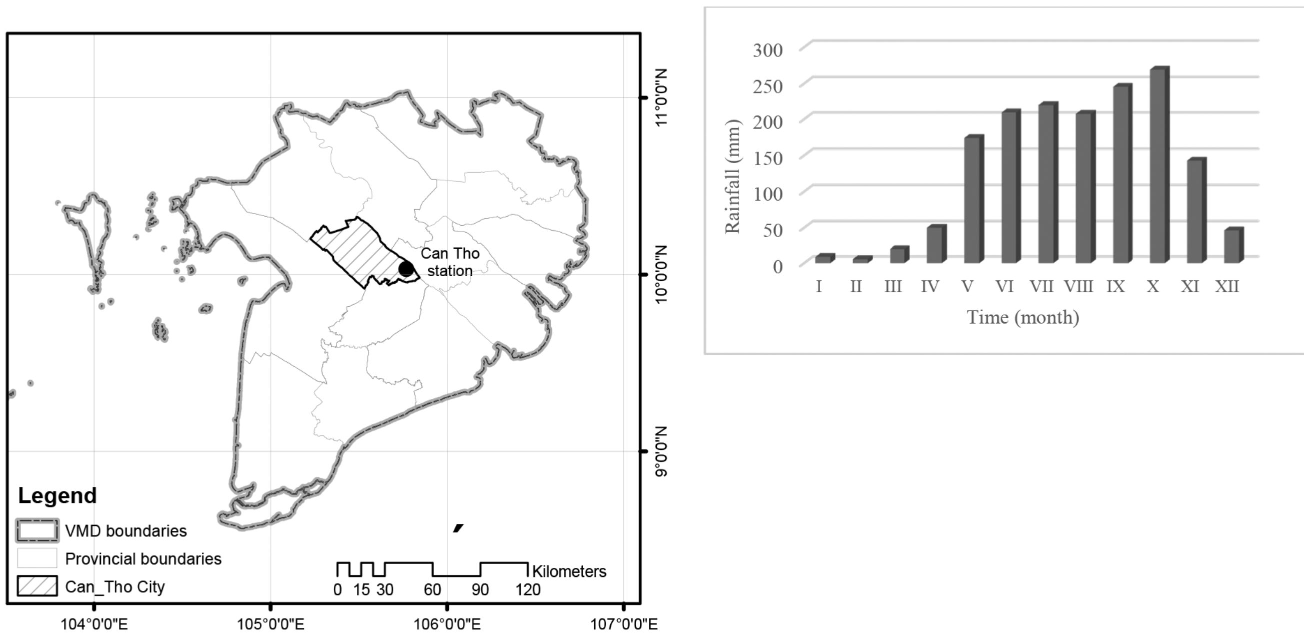


Figure 1: Location of Can Tho City (a) and average monthly temperature at Can Tho City (1984-2022) (b).

The monthly high rainfall occurred near the end of the wet season (October with 269 mm, accounting for 17% of the normal yearly rainfall). The average number of rainfall days is 154.

B. Technique

Exploratory data analysis involves the use of statistical techniques to identify patterns that may be hidden in a group of numbers. One of these techniques is the "Box plot," which is used to visually summarise and compare groups of data (Williamson et al., 1989). Mann-Kendall test and sequential trend analysis (SMK) were non-parameter tests that were also conducted in many studies in order to answer whether climate factor changes or not (Xuan et al., 2022; Dawood et al., 2017), see reference for methodology (Hamed et al., 1998).

Results

Maximum Temperature Assessment Using Description Analysis, Mann-Kendall Test and SMK Test

Figure 2 and Table 1 depicts a box plot of Can Tho City's monthly average maximum temperature for a 39-year period (1984-2022). The month of January began with a mean temperature of 30.4°C, and then climbed to a maximum of 33.8°C in April. Following that, the temperature gradually decreased and achieved its lowest T_{max} value in December. The mean of T_{max} monthly is nearly higher than a monthly medium of T_{max} exception with of January, June, August and September. Although this difference is not significant, it demonstrates that numerous extreme values occur in the months of February, March, April, May, July, October, November, and December.

Results for every average T_{max} of 5-year show the rapid increase in average T_{max} in the period after 2010 to 2020 (Figure 3). Between 1985 and 2022, the average T_{max} increased consistently and fast. We can see that it grew faster between 2015 and 2020 than from the period 2010 to 2015. However, between 2020 and 2022, the average T_{max} tends to decrease. As a result, we must continue to study the trend until 2020 to see how the average T_{max} changes. The occurrence of record-high temperatures is an indicator of long-term changes in extreme heat. However, a study by Thang et al. identified that 2016 and 2020 were the years with the highest average temperatures measured over global land areas, and 2019 was the year that the greatest number of countries reported as being the warmest year of the decade (Nguyen et al., 2017). 2016 -2017, 2017-2018 were recorded as El Nino years and 2018-2019 was recorded as El Nino.That is why this period is a general sign showing the rapidly increasing trend of T_{max} over time at Can Tho station. We anticipate that Can Tho station will experience growth throughout the year. We utilize a non-parameter test to look at the trend of average T_{max}.

Table 2 shows the Mann-Kendal test results for the maximum monthly temperature at Can Tho. Monthly maximum temperature data at 12 months have increased. The monthly maximum temperature data in

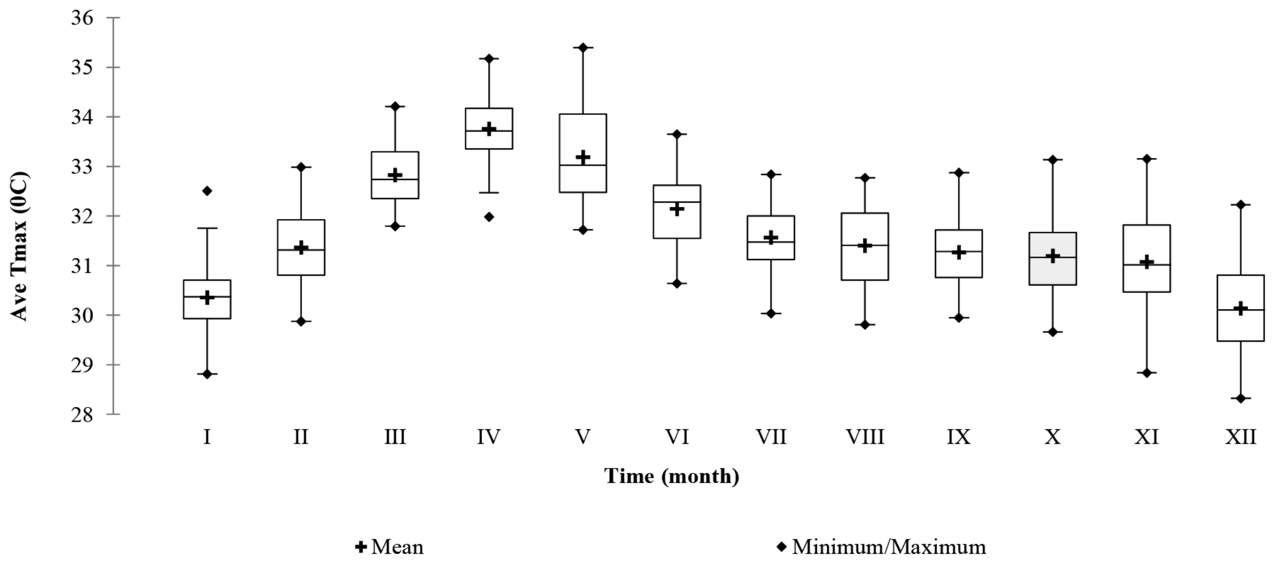


Figure 2: Box plot for average maximum temperature at Can Tho station, during 1984 and 2022.

Table 1: Description analysis for monthly of T_{max} at Can Tho City

Statistic	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*
Nbr. of observations	39	39	39	39	39	39	39	39	39	39	39	39
Minimum	28.816	29.876	31.797	31.983	31.723	30.640	30.035	29.810	29.950	29.665	28.840	28.326
Maximum	32.510	32.986	34.210	35.173	35.397	33.650	32.839	32.771	32.873	33.135	33.153	32.226
Range	3.694	3.110	2.413	3.190	3.674	3.010	2.803	2.961	2.923	3.471	4.313	3.900
1st Quartile	29.932	30.809	32.352	33.353	32.477	31.550	31.123	30.708	30.758	30.608	30.467	29.476
Median	30.371	31.314	32.739	33.717	33.023	32.280	31.477	31.410	31.283	31.168	31.013	30.106
3rd Quartile	30.708	31.926	33.295	34.172	34.056	32.618	32.002	32.060	31.720	31.666	31.818	30.810
Mean	30.357	31.367	32.826	33.759	33.190	32.147	31.570	31.405	31.270	31.195	31.079	30.139
Variance (n-1)	0.712	0.614	0.460	0.429	0.935	0.508	0.421	0.639	0.559	0.688	0.961	1.010
Standard deviation (n-1)	0.844	0.784	0.678	0.655	0.967	0.713	0.649	0.799	0.747	0.830	0.980	1.005

Table 2: Maximum monthly temperature at Can Tho

Time (month)	*^{0}C/decade*	*Time (month)*	*^{0}C/decade*	*Time (month)*	*^{0}C/decade*	*Time (month)*	*^{0}C/decade*
I	0.31	II	0.43	III	0.42	IV	0.26
V	0.35	VI	0.49	VII	0.35	VIII	0.58
IX	0.50	X	0.53	XI	0.65	XII	0.49

Table 3: Description analysis for monthly of T_{min} at Can Tho City

Statistic	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*
Nbr. of observations	39	39	39	39	39	39	39	39	39	39	39	39
Minimum	21.087	21.479	23.094	24.500	24.358	23.787	23.835	23.832	23.743	23.742	23.233	21.274
Maximum	24.606	24.582	25.155	26.283	27.029	25.790	25.816	25.510	25.490	25.416	29.940	25.113
Range	3.519	3.104	2.061	1.783	2.671	2.003	1.981	1.677	1.747	1.674	6.707	3.839
1st Quartile	22.061	22.496	23.800	24.878	24.948	24.590	24.190	24.248	24.248	24.248	24.198	22.781
Median	22.790	22.996	24.245	25.297	25.223	24.790	24.426	24.594	24.550	24.500	24.523	23.094
3rd Quartile	23.397	23.580	24.705	25.708	25.629	25.215	24.798	24.766	24.782	24.787	24.833	23.626
Mean	22.762	22.998	24.256	25.319	25.395	24.868	24.517	24.574	24.533	24.554	24.634	23.248
Variance (n-1)	0.719	0.565	0.315	0.284	0.444	0.227	0.188	0.185	0.149	0.155	1.131	0.791
Standard deviation (n-1)	0.848	0.752	0.561	0.533	0.667	0.476	0.433	0.431	0.385	0.393	1.064	0.889

November has the highest increase, with Sen's slope of 0.58 ^{o}C/decade. The monthly maximum temperature data in Apr has the lowest increase, with Sen's slope of 0.26 ^{o}C/decade.

Figure 4 depicts the T_{max} in dry season months XII, I, II, II, IV, V, and VI, which increased at a 95% confidence level, starting in 2008, 2015, 2011, 2005, 2013, and 2015 respectively. Similarly, T_{max} in the wet season months VII, VIII, IX, X, XII, and XII started increasing at a 95% confidence level, starting in 2008, 2011, 2006, 2000, 2001, 2002, and 2008, respectively. The temperature T_{max} rises earlier in the wet season than in the dry season.

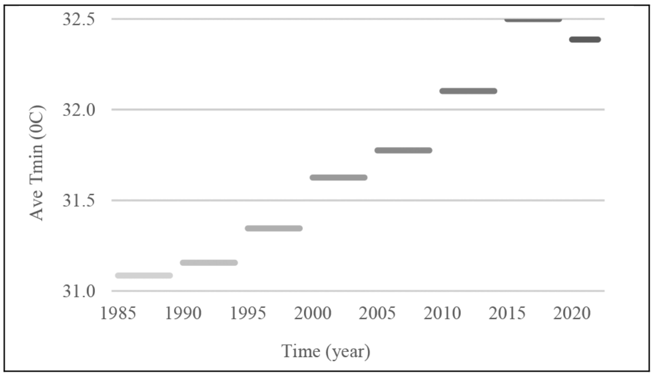
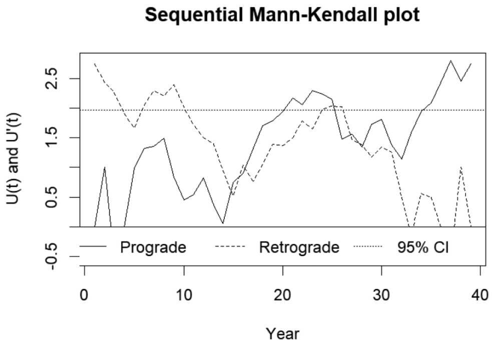


Figure 3: Average maximum temperature for every 5-year at Can Tho station.

Minimum Temperature Assessment Using Description Analysis, Mann-Kendall Test, and SMK

Figure 5 and Table 3 depict a box plot of Can Tho City's monthly average minimum temperature for a 39-year period (1984-2022). The lowest T_{min} happened in Jan and highestTmin happened in May. T_{min} started increasing in from Dec to May, and then slightly decreased in Jun. T_{min} nearly constant from July to Nov.

Figure 6 demonstrates that the rate of increase in T_{min} was lower than that in T_{max} (Figure 3), and it is divided into three eras of T_{min} increase (1985-1995, 1996-2010, and 2011-2022). The average T_{min} has increased with



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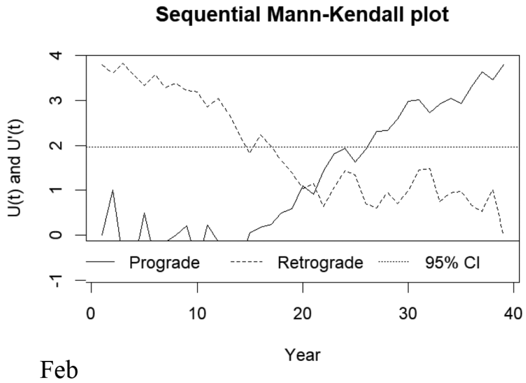

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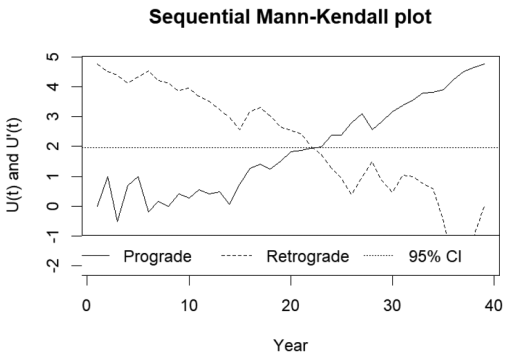

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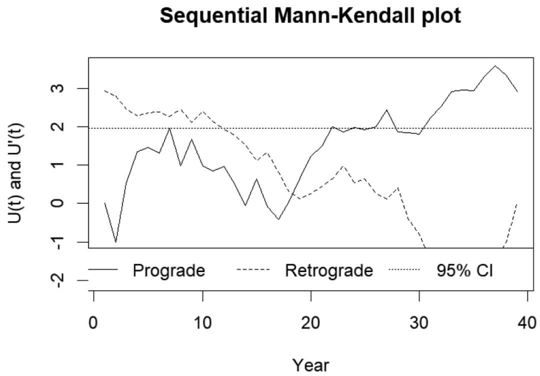

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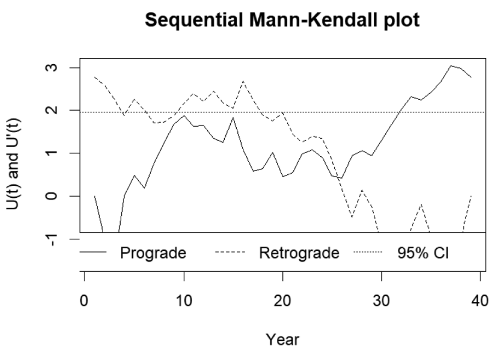

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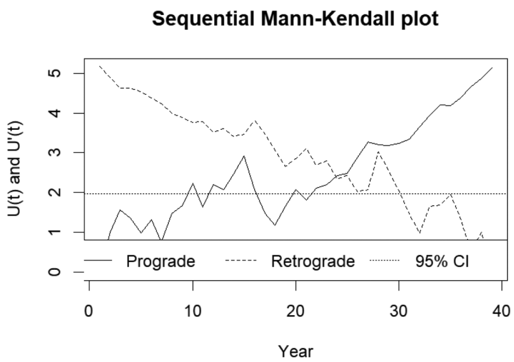

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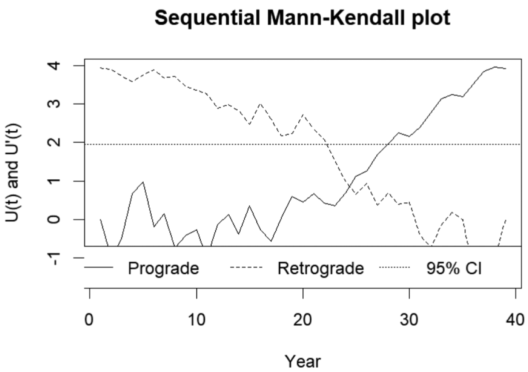

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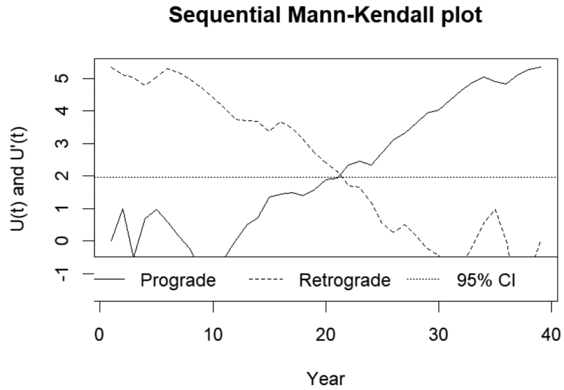

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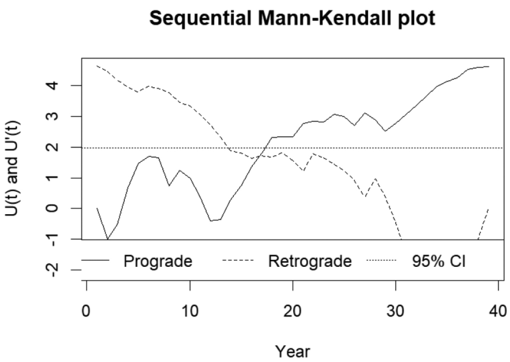

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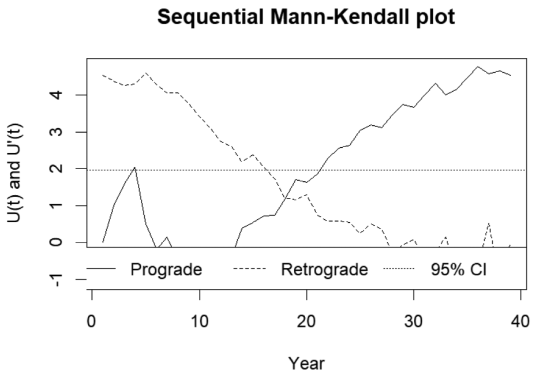

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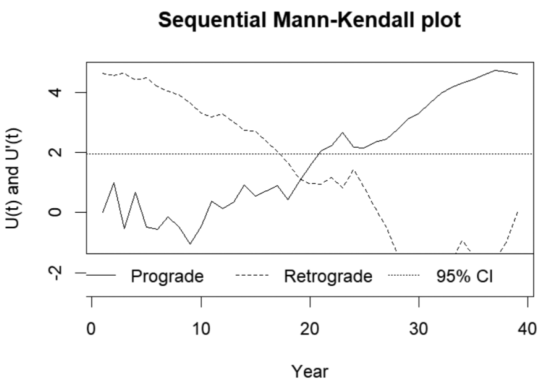

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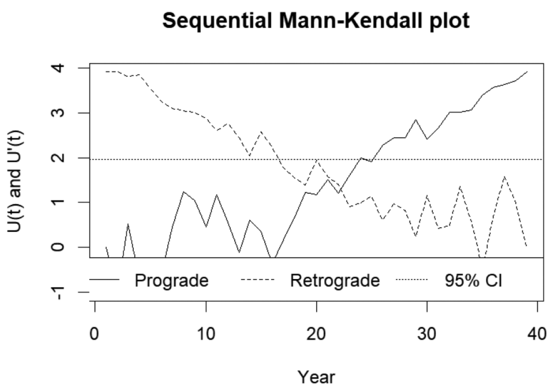

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Figure 4: SMK result for monthly maximum temperature.

Table 4: Minimum monthly temperature at Can Tho

Time (month)	*°C/decade*	*Time (month)*	*°C/decade*	*Time (month)*	*°C/decade*	*Time (month)*	*°C/decade*
I	0.4	II	0.28	III	0.33	IV	0.33
V	0.30	VI	0.28	VII	0.23	VIII	0.27
IX	0.22	X	0.22	XI	0.26	XII	0.4

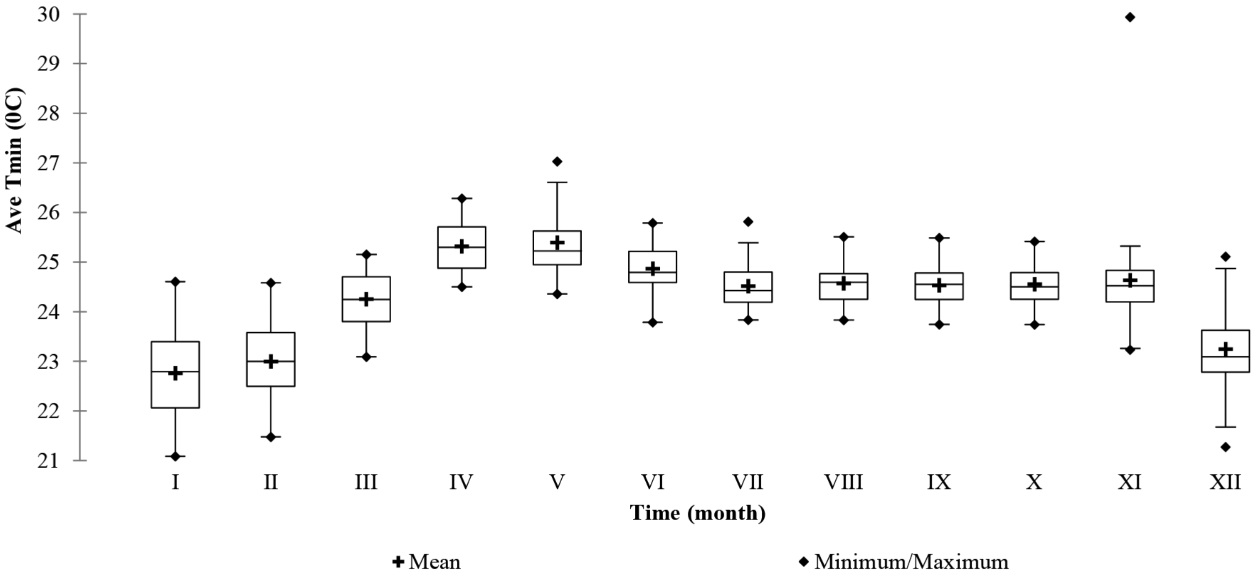


Figure 5: Box plot for average minimum temperature at Can Tho station, during 1984 and 2022.

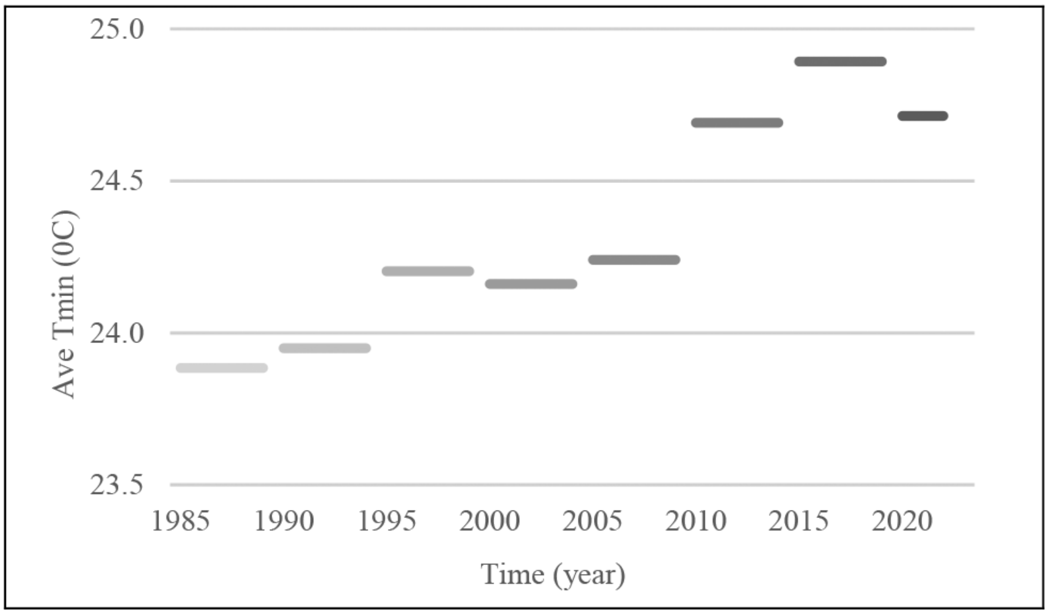


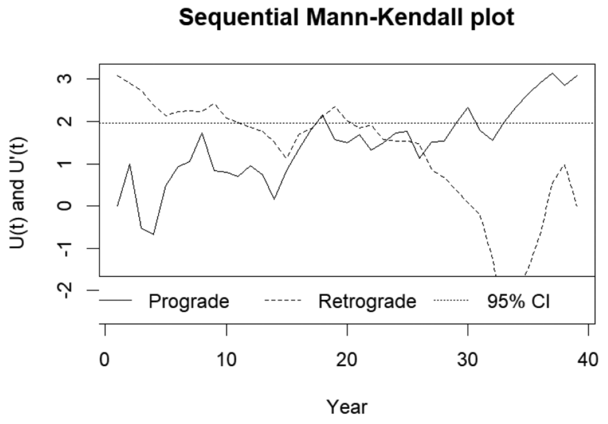
Figure 6: Average minimum temperature for every 5-year at Can Tho station.

Sen's slope of 0.29 ^{o}C/decade, while T_{max} has increased with Sen's slope of 0.45 ^{o}C/decade (Table 4).

Figure 7 depicts the T_{min} in dry season months XII, I, II, II, IV, V, and VI, which increased at a 95% confidence level, starting in 2016, 2016, 2008, 2002, 2012, and 2007. Similarly, T_{min} in the wet season months VII, VIII, IX, X, XII, and XII started increasing at a 95% confidence level, starting in 2012, 2011, 2008, 2012, 2001, 2013, and 2008, respectively. The temperature T_{min} rises slightly earlier in the wet season than in the dry season. In general, T_{max} began to increase in temperature earlier than T_{min} at Can Tho station. It should be noted that when T_{min} increases, it is a sign that the temperature in Can Tho tends to increase.

Conclusion

T_{max} and T_{min} increased for all 12 months from 1984 to 2022, with Sen's slopes of 0.45 ^{o}C/decade and 0.29 ^{o}C/decade, respectively. Although T_{min} shows a slower



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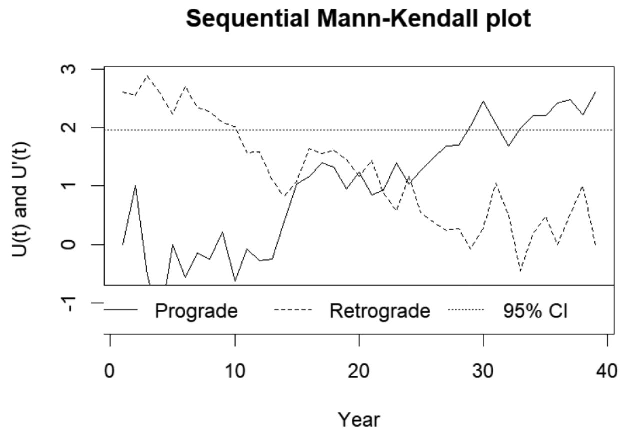

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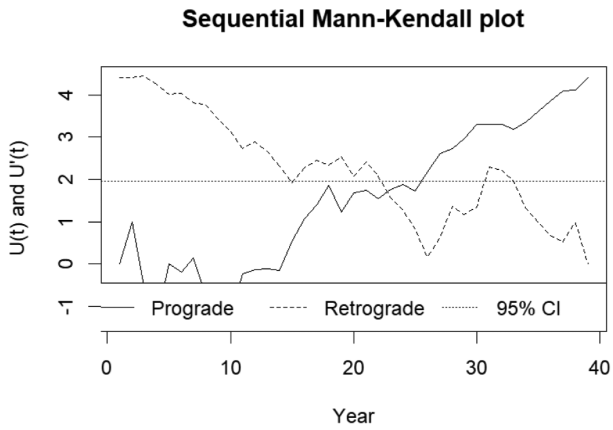

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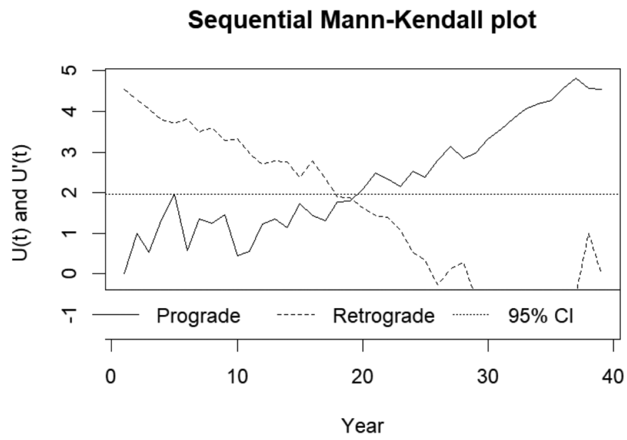

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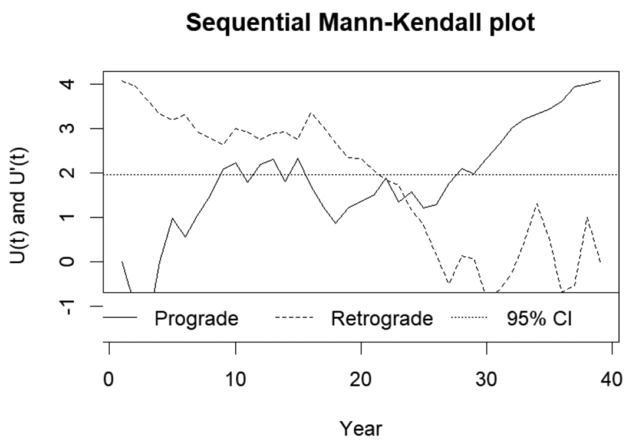

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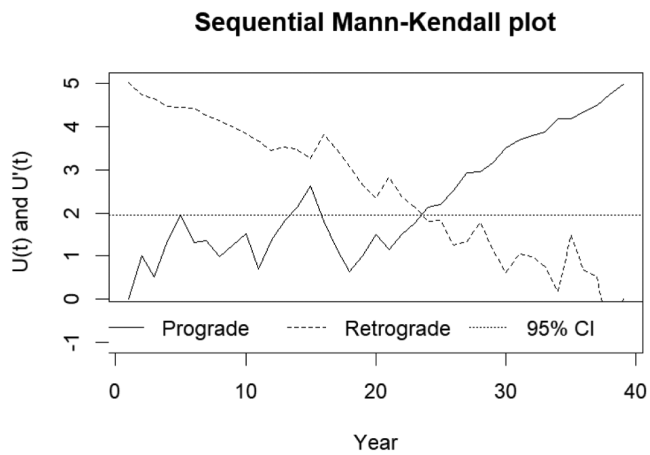

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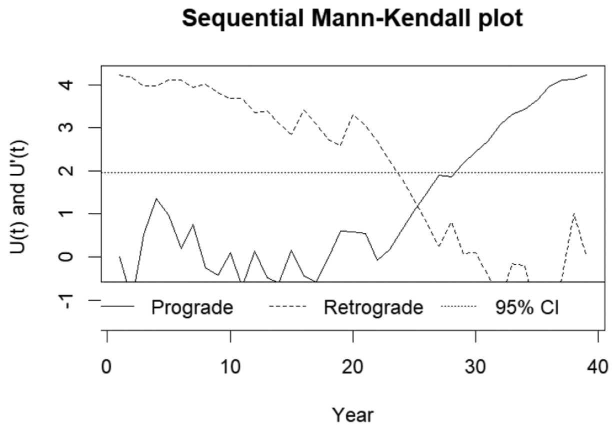

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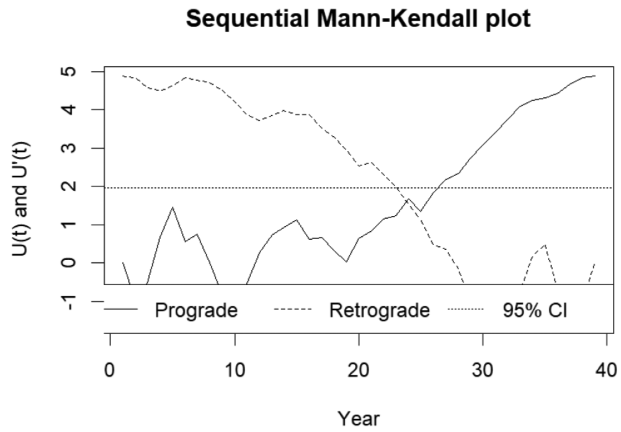

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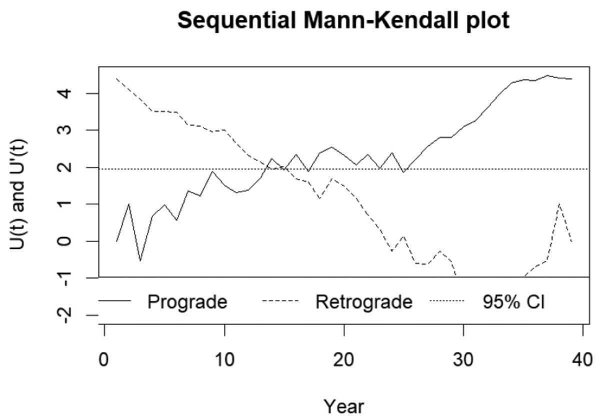

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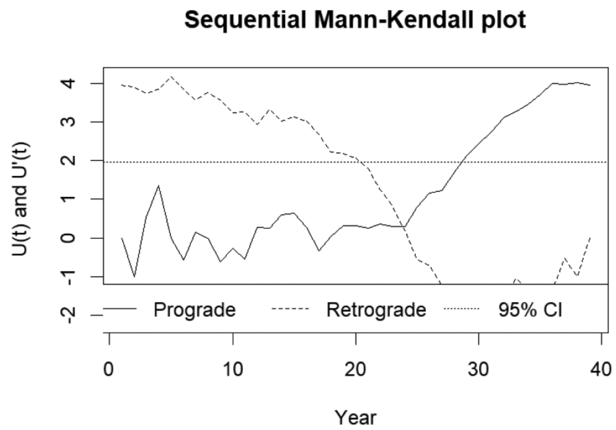

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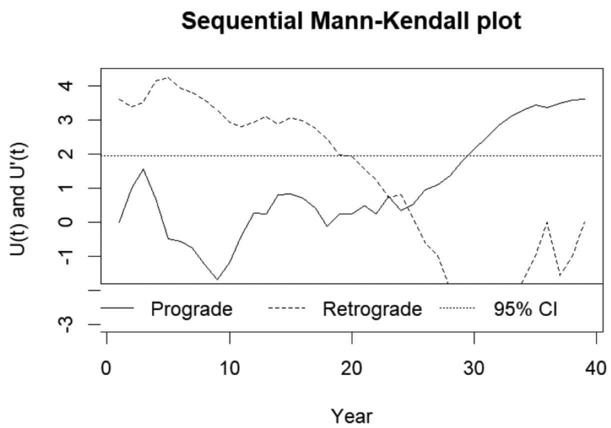

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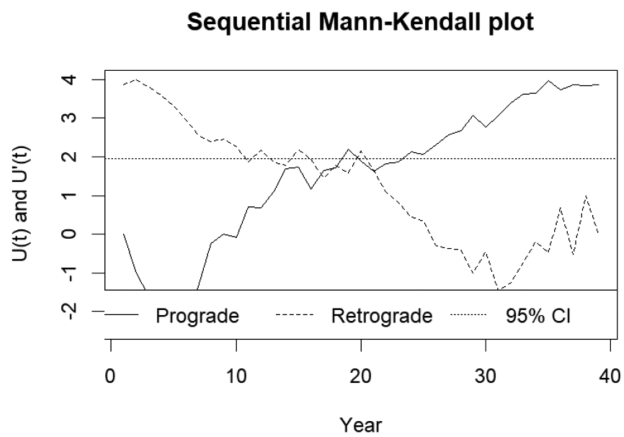

Dec

Figure 7: SMK result for monthly minimum temperature.

rate of increase than T_{max}, the increase in T_{min} indicates that the temperature in Can Tho has risen.

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