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# DETERMINING THE STEADY-STATE PROBABILITY FOR THE DAILY MAXIMUM TEMPERATURE IN PENINSULAR MALAYSIA USING MARKOV CHAIN

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**ABSTRACT**

***The objective of this study was to determine the steady-state probability for the daily maximum temperature in Peninsular Malaysia. Data of daily maximum temperature from Malaysian Meteorological Department were analyzed. Ten stations in Peninsular Malaysia were examined. The transition count, chi-square test, transition probability and steady-state probability were obtained. The steady-state probability results showed that after a sufficiently long time, there was a high probability for the stations to encounter the slightly warm temperature, with the range of maximum temperature from 30.1°C to 34.0°C, except Chuping and Alor Setar tend to be warmer with the range of maximum temperature from 38.1°C to 42.0°C and Muadzam Shah tend to be in warm state with the range of maximum temperature from 34.1°C to 38.0°C. The importance of knowing the steady-state probability of slightly cool, neutral, slightly warm, warm and hot temperature would help the citizens with the awareness and effects of climate warming.***

**Keywords:** *daily maximum temperature; Markov Chain; steady-state probability.*

## 1. INTRODUCTION

As defined by Wikipedia, “temperature is an objective comparative measure of hot or cold” (Wikipedia, 2016). Field *et al.* (2012) suggested many places in the world are suffering from climate warming. Gayo and Tolosa (2015) proposed the earth is getting warmer unless drastic actions were taken to reduce the effects of heat globally. Water resources, coastal resources, forestry, agriculture and health were some of the impacts of climate change.

Dai *et al.* (2016) suggested in the study the need to assess climate trends for agriculture. The data for the study were during the period of 1980 up to 2013 for 12 Midwestern US states and the result showed that during the end of the growing season especially in September, the maximum temperature rose faster. Wolfe (2013) stated the risk of crop failure increased because of climate warming. According to Gan *et al.* (2015), the daily maximum temperature was predicted to increase by up to 8.0°C in Africa.

Lumioan (2011) reported in Philippine Daily Inquirer that the maximum recorded temperature of all-time in National Capital Region, Philippine was on May 14, 1987, which was recorded as 38.5°C. The frequency of hot days and warm nights in many locations in Philippine had significantly increased during 1960 until 2003 as reported by Philippine Atmospheric,

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Geophysical & Astronomical Services Administration (PAGASA) in Gayo and Tolosa (2015).

According to Tan *et al.* (2007), heat wave occurred when the daily maximum temperature for a specified number of days exceeded a critical threshold defined medically. National Weather Service illustrated heat wave as “a period of abnormally and uncomfortably hot and unusually humid weather” with length of two or more days (National Weather Service, 2016). Kunst *et al.* (1993), Curriero *et al.* (2002) and Hajat *et al.* (2002) in Keellings and Waylen (2011) suggested high temperature could increase death rates when temperature rose above the local population’s threshold or critical value.

In measuring the risk of high temperature events above the critical temperature threshold, Keellings and Waylen (2011) built simple stochastic models. The study used the historic datasets maximum daily temperature from meteorological stations in Lake City, DeFuniak Springs, Avon Park, and Fort Myers, Florida from 1890s to 2008. The study reflected the significance of statistical stochastic variables related to the events of the high temperature or heat waves. Nott *et al.* (2001) used daily maximum temperature data of 29 stations in the Sydney area to illustrate the used of Markov chain methods for computation. Barkotulla and Rahman (2012) investigated prediction transition probabilities for environmental impact analysis and concluded that the Markov chain model was suitable in the field of environmental sciences.

Hasan (2015) studied the long-run proportion of time for the daily maximum temperature for five stations in the Northern part of Malaysia for the duration of ten years. The result showed that after a sufficiently long time, Malaysia would still be experiencing slightly warm temperature. Bernama (2016) reported Chuping and Alor Setar experienced hot weather with the recorded temperature 39.1°C and 39.0°C respectively.

The objective of this study was to determine the steady-state probability for the daily maximum temperature for ten stations in Peninsular Malaysia for the duration of twenty years. This study was a further exploration on the study done by Hasan (2015). The importance of knowing the steady-state probability the range of maximum temperature for each studied stations whether it was slightly cool, neutral, slightly warm, warm and hot temperature would help the citizens with the awareness and effects of climate warming.

The secondary data of daily maximum temperature from Malaysian Meteorological Department were analyzed. Ten stations in Peninsular Malaysia were examined; Chuping, Alor Setar, Bayan Lepas, Kota Bharu, Kuala Terengganu, Muadzam Shah, KLIA, Malacca, Mersing and Senai. Data of daily maximum temperature were from January 1, 1994 up to December 31, 2013 except KLIA which are from July 1, 1998 up to December 31, 2013.

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## 2. METHODOLOGY

As mentioned, the data of daily maximum temperature comprised of ten stations in Peninsular Malaysia. These stations were chosen to represent several locations in Peninsular Malaysia. The transition count, chi-square test, transition probability and steady-state probability were obtained.

According to Gayo and Tolosa (2015), Markov Chain process is "where the outcome of a given experiment can affect the outcome of the next experiment". Referring to Adam (2016), the Markov Chain stochastic process with continuous parameter $X_n$, $n \geq 0$:

$$P[X_{n+1} = j / X_n = i, X_{n-1} = i, n-1 \ldots X_1 = i, X_0] = P_{ij} \ldots (1)$$

for all states $i_1, \ldots, i_{n-1}, i, j$ and $n \geq 1$.

Hasan (2015) stated the transition count matrix, $M_{n \times n} = [M_{ij}]$ where $\{i = 1,2,\ldots, n;\ j = 1,2,\ldots, n\}$ and $n$ depended on the number of states present.

The chi-square test was used to test the independent of the stations. According to McClave *et al.* (2014), the formula for the chi-square statistic used in the chi square test was

$$X_c^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

where the subscript "c" was the degrees of freedom, "O" was the observed value of the frequency states of transition for daily maximum temperature and E was the expected value states of transition for daily maximum temperature.

Table 1 shows the states of transition and range of temperature according to Lin and Matzarakis (2008) to determine the state of transition for this study.

Table 1: State of Transition and Range of Temperature

| State of transition | Range of temperature |
|---|---|
| Slightly cool (C) | 22.1 – 26.0 |
| Neutral (N) | 26.1 – 30.0 |
| Slightly warm (S) | 30.1 – 34.0 |
| Warm (W) | 34.1 – 38.0 |
| Hot (H) | 38.1 – 42.0 |

## 3. RESULTS AND DISCUSSION

### *3.1 The Lowest and Highest Daily Maximum Temperature for Each Station*

The results in Table 2 show the lowest and highest daily maximum temperature for each station. The results show the lowest daily maximum temperatures are between 23.3ºC to 25.1ºC. Therefore, all stations fell in the category slightly cool state of transition for the

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lowest daily maximum temperature. Chuping station had the highest daily maximum temperature, 40.1ºC followed by Alor Setar station, 39.1ºC, which fall into the category of hot state of transition. While other stations fell in the category warm state of transition for the highest daily maximum temperature.

Table 2: The Lowest and Highest Daily Maximum Temperature for Each Station

| Location | Lowest Daily Maximum Temperature | Highest Daily Maximum Temperature |
|---|---|---|
| Chuping | 23.7 | 40.1 |
| Alor Setar | 24.8 | 39.1 |
| Bayan Lepas | 25.1 | 35.6 |
| Kota Bharu | 23.8 | 36.4 |
| Kuala Terengganu | 23.8 | 35.8 |
| Muadzam Shah | 23.3 | 37.3 |
| KLIA | 24.2 | 37.2 |
| Melaka | 24.4 | 38.0 |
| Mersing | 23.6 | 36.2 |
| Senai | 23.4 | 37.2 |

### *3.2 Transition Count for Daily Maximum Temperature*

Table 3 shows the frequency states of transition for each ten stations in Peninsular Malaysia. The results illustrated that most of the maximum daily temperature for these ten stations were slightly warm, which are between 30.1ºC to 34.0ºC. Chuping in Perlis and Alor Setar in Kedah encountered hot temperature, with the range daily maximum temperature between 38.1ºC to 42.0ºC.

Table 3: Frequency States of Transition for Daily Maximum Temperature

| Location | State of Transition | | | | |
|---|---|---|---|---|---|
| | Slightly cool | Neutral | Slightly warm | Warm | Hot |
| Chuping | 30 | 568 | 5084 | 1587 | 35 |
| Alor Setar | 22 | 529 | 5325 | 1400 | 5 |
| Bayan Lepas | 6 | 721 | 6418 | 159 | 0 |
| Kota Bharu | 61 | 1593 | 5465 | 185 | 0 |
| Kuala Terengganu | 53 | 1441 | 5620 | 190 | 0 |
| Muadzam Shah | 92 | 835 | 4761 | 1610 | 0 |
| KLIA | 7 | 507 | 4748 | 400 | 0 |
| Melaka | 20 | 611 | 6113 | 560 | 0 |
| Mersing | 85 | 1809 | 5233 | 177 | 0 |
| Senai | 62 | 944 | 5817 | 481 | 0 |

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### 3.3 ***Chi-square Test***

A test of independence using Chi-square test was performed. The null hypothesis statement was the states of transition were independent of the stations. The alternative hypothesis statement was the states of transition were dependent of the stations. For the possibility of the chi-square test result for this study, the frequency states of transition count for daily maximum temperature for warm and hot were combined. The test statistics obtained was 7454.0209 with the p-value of 0.0000. The null hypothesis was rejected. The chi-square result showed that the states of transition were significantly dependent of the stations.

### ***3.4 Transition Probability for Daily Maximum Temperature***

Table 4 shows the transition probability for daily maximum temperature for ten stations. We can see that both Chuping and Alor Setar stations showed no records of the transition from the state of slightly cool moving to the state of hot. There were no records of the transition from the state of slightly cool moving to the state of warm and hot for all other stations in Peninsular Malaysia. In addition, all stations showed no evidence of the warm state moving to slightly cool state, except for Chuping station with a very small probability 0.0006.

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Table 4: Transition Probability for Daily Maximum Temperature

| Location | | State of transition | | | | |
|---|---|---|---|---|---|---|
| | | Slightly cool (C) | Neutral (N) | Slightly warm (S) | Warm (W) | Hot (H) |
| Chuping | C | 0.0667 | 0.5000 | 0.4333 | 0.0000 | 0.0000 |
| | N | 0.0264 | 0.2817 | 0.6849 | 0.0070 | 0.0000 |
| | S | 0.0024 | 0.0751 | 0.8236 | 0.0985 | 0.0004 |
| | W | 0.0006 | 0.0069 | 0.3119 | 0.6698 | 0.0107 |
| | H | 0.0000 | 0.0000 | 0.0000 | 0.5429 | 0.4571 |
| Alor Setar | C | 0.0000 | 0.5000 | 0.5000 | 0.0000 | 0.0000 |
| | N | 0.0151 | 0.2722 | 0.7032 | 0.0095 | 0.0000 |
| | S | 0.0026 | 0.0684 | 0.8505 | 0.0785 | 0.0000 |
| | W | 0.0000 | 0.0071 | 0.2950 | 0.6950 | 0.0029 |
| | H | 0.0000 | 0.0000 | 0.0000 | 0.8000 | 0.2000 |
| Bayan Lepas | C | 0.0000 | 0.5000 | 0.5000 | 0.0000 | |
| | N | 0.0042 | 0.2621 | 0.7337 | 0.0000 | |
| | S | 0.0005 | 0.0824 | 0.9004 | 0.0167 | |
| | W | 0.0000 | 0.0000 | 0.6730 | 0.3270 | |
| Kota Bharu | C | 0.1967 | 0.6885 | 0.1148 | 0.0000 | |
| | N | 0.0264 | 0.6842 | 0.2888 | 0.0006 | |
| | S | 0.0013 | 0.0840 | 0.8935 | 0.0212 | |
| | W | 0.0000 | 0.0108 | 0.6216 | 0.3676 | |
| Kuala Terengganu | C | 0.0755 | 0.6415 | 0.2830 | 0.0000 | |
| | N | 0.0264 | 0.6440 | 0.3296 | 0.0000 | |
| | S | 0.0020 | 0.0851 | 0.8980 | 0.0149 | |
| | W | 0.0000 | 0.0053 | 0.4368 | 0.5579 | |
| Muadzam Shah | C | 0.2609 | 0.5000 | 0.2391 | 0.0000 | |
| | N | 0.0515 | 0.3760 | 0.5401 | 0.0323 | |
| | S | 0.0053 | 0.0914 | 0.7477 | 0.1556 | |
| | W | 0.0000 | 0.0254 | 0.4516 | 0.5230 | |
| KLIA | C | 0.1429 | 0.2857 | 0.5714 | 0.0000 | |
| | N | 0.0059 | 0.1992 | 0.7909 | 0.0039 | |
| | S | 0.0006 | 0.0842 | 0.8673 | 0.0478 | |
| | W | 0.0000 | 0.0100 | 0.5650 | 0.4250 | |
| Malacca | C | 0.2000 | 0.4500 | 0.3500 | 0.0000 | |
| | N | 0.0115 | 0.1849 | 0.8036 | 0.0000 | |
| | S | 0.0015 | 0.0788 | 0.8757 | 0.0440 | |
| | W | 0.0000 | 0.0125 | 0.4679 | 0.5196 | |
| Mersing | C | 0.1765 | 0.6824 | 0.1412 | 0.0000 | |
| | N | 0.0310 | 0.5959 | 0.3698 | 0.0033 | |
| | S | 0.0027 | 0.1261 | 0.8488 | 0.0224 | |
| | W | 0.0000 | 0.0734 | 0.6215 | 0.3051 | |
| Senai | C | 0.1613 | 0.5484 | 0.2903 | 0.0000 | |
| | N | 0.0297 | 0.2595 | 0.6981 | 0.0127 | |
| | S | 0.0041 | 0.1126 | 0.8379 | 0.0454 | |
| | W | 0.0000 | 0.0229 | 0.5509 | 0.4262 | |

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### *3.5 Steady-State for Daily Maximum Temperature*

Table 5 shows the results of steady state or achieved the limit probabilities for daily maximum temperature for ten stations. After a sufficiently long time, there was a high probability for the studied stations in Peninsular Malaysia encounter the slightly warm temperature, with the range of maximum temperature from 30.1°C to 34.0°C.

Bayan Lepas, KLIA and Malacca stations are among the lowest steady-state proportion encountered slightly cool temperature but among the highest steady-state proportion encountered slightly warm temperature, compared to the other seven stations. The result of this study consistent with Hasan (2015) that there was a high probability for the stations in Peninsular Malaysia encountered the slightly warm temperature followed by warm temperature.

The Mersing station had the highest steady-state proportion encountered neutral temperature, with the range of daily maximum temperature from 26.1°C to 30.0°C, followed by Kota Bharu and Kuala Terengganu stations. The Bayan Lepas station had the highest steady-state proportion encountered slightly warm temperature, with the range of daily maximum temperature from 30.1°C to 34.0°C, followed by KLIA and Malacca stations. The Chuping and Muadzam Shah stations had the highest steady-state proportion encountered the warm temperature, with the range of daily maximum temperature from 34.1°C to 38.0°C, followed by Alor Setar station.

The Chuping and Alor Setar stations were the only stations encountered the hot temperature, with the range of daily maximum temperature from 38.1°C to 42.0°C. The result that Chuping and Alor Setar experienced hot temperature consistent with Bernama (2016) which reported Chuping and Alor Setar experienced hot weather with the recorded temperature 39.1°C and 39.0°C respectively. The significance of this study compared to Hasan (2015) was the additional results that Chuping and Alor Setar experienced hot temperature, and Muadzam Shah encountered warm temperature due to the duration the data of daily maximum temperature for twenty years with ten locations in Peninsular Malaysia.

Table 5: Limiting Probabilities for Daily Maximum Temperature

| | State of Transition | | | | |
|---|---|---|---|---|---|
| Location | Slightly cool | Neutral | Slightly warm | Warm | Hot |
| Chuping | 0.0041 | 0.0778 | 0.6961 | 0.2173 | 0.0048 |
| Alor Setar | 0.0030 | 0.0727 | 0.7314 | 0.1923 | 0.0007 |
| Bayan Lepas | 0.0008 | 0.0987 | 0.8787 | 0.0218 | |
| Kota Bharu | 0.0084 | 0.2181 | 0.7482 | 0.0253 | |
| Kuala Terengganu | 0.0073 | 0.1973 | 0.7694 | 0.0260 | |
| Muadzam Shah | 0.0126 | 0.1146 | 0.6522 | 0.2206 | |
| KLIA | 0.0012 | 0.0896 | 0.8388 | 0.0704 | |
| Malacca | 0.0027 | 0.0837 | 0.8369 | 0.0767 | |
| Mersing | 0.0116 | 0.2477 | 0.7165 | 0.0242 | |
| Senai | 0.0085 | 0.1294 | 0.7963 | 0.0658 | |

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## 4. CONCLUSION

Data of daily maximum temperature for ten locations were analysed. The objective of this study was to determine the steady-state probability for the daily maximum temperature in Peninsular Malaysia. The steady-state results showed that after a sufficiently long time, there was a high probability for the studied stations in Peninsular Malaysia encountered the slightly warm temperature, with the range of maximum temperature from 30.1°C to 34.0°C. The objective of this study to determine the steady-state probability for the daily maximum temperature in Peninsular Malaysia was successfully achieved. By determining the steady-state probability for the daily maximum temperature in Peninsular Malaysia, the state of transition for each of the studied stations can be determined. The importance of knowing the steady-state probability the range of maximum temperature for each studied stations whether it was slightly cool, neutral, slightly warm, warm, and hot temperature would help the citizens with the awareness and effects of climate warming.

In conclusion, after a sufficiently long time, there was a high probability for the studied stations in Peninsular Malaysia encountered the slightly warm temperature, with the range of maximum temperature from 30.1°C to 34.0°C, except Chuping and Alor Setar tended to be hotter with the range of maximum temperature from 38.1°C to 42.0°C and Muadzam Shah tended to be in warm state with the range of maximum temperature from 34.1°C to 38.0°C.

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