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The Relationship between Diurnal Temperature Range (DTR) and Rainfall over Northern Thailand

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Abstract. Since 1950, it has been found that the global diurnal temperature range (DTR), the difference between the minimum temperature (T_{min}) and the maximum temperature (T_{max}) of daily surface air temperature, has been temporally decreasing in several places all over the world. The aim of this study is to investigate the effect of DTR on the amount of total monthly rainfall (TRF) and the number of rainy days per month (RD), as well as to evaluate the possibility of using DTR as a parameter in the rainfall prediction process. The study area is in northern Thailand, which covers about one third of the total area of the country. The impact of DTR on rainfall over the studied area is evaluated from the relationship between DTR and TRF, as well as DTR and RD, by using long-term meteorological monthly data over 30 years (1978-2007). Besides, the relationships of RD, TRF, and the temperature of mean monthly T_{max} and T_{min} are also analysed. The significance of the correlation between the two parameters is identified by the coefficient of correlation. The possibility of using DTR is evaluated by estimating the relationships between DTR and a one month-lag time of RD and TRF. It is found that the DTR has a strong statistically significant (> 99%) negative correlation with TRF and RD, as well as with the one month-lag time of TRF and RD. Therefore, it is possible to consider DTR as a significant parameter for rainfall prediction.

1. Introduction

Temperature is one of the most significant parameters for meteorologists to observe the change of climate over time. In 1950, the global diurnal temperature range (DTR), the difference between the minimum temperate (T_{min}) and the maximum temperature (T_{max}), of surface air temperature was introduced, and it was found that DTR has been temporally decreasing in several places all over the world [1,2,3]. For the northern hemisphere, the decrease of DTR occurred because the increase in the rate of T_{min} was higher than that of the T_{max} [1,2,4]. Although the global DTR from 1950 to 2010 shows a net decrease of -0.04°C ±0.01 dec^{-1}, the average worldwide DTR trend has been increasing since the late 1980s [5].

There are several primary factors that cause the impact on the DTR, e.g., greenhouse gases, aerosols, urban heat, water vapor, and changing land use/cover, but the main factors are precipitation, cloud cover, and soil moisture [1,4,6,7,8,9,10]. However, these main factors are the consequential effect from those primary factors [1].

On the other hand, several studies described an inverse relationship between DTR and cloud cover as well as between DTR and precipitation and revealed that increasing cloud cover and precipitation can make DTR decrease significantly [7,11]. A strong and statistically significant negative correlation between the average annual DTR and average annual cloud cover/precipitation as well as between the seasonal DTR and the seasonal precipitation has also been found [11,12]. By using the daily data from the First International Satellite Land Surface Climatology Project (ISLSP), Flied Experiment (FIFE), and worldwide meteorological stations, it has been shown that clouds, soil moisture, and precipitation cause the reduction of the DTR range by over 50% [7].

Because Thailand is an agricultural country under the influence of the tropical monsoon, it is important to understand the rainfall behaviour in order to improve water management efficiency. Due to the effect of climate change, temperature over the world is increasing. This study, therefore, focuses on the parameter of DTR which is the dependent variable of temperature. This study investigates the effect of DTR on the amount of total monthly rainfall, and the number of rainy days per month. The DTR trend and the correlation between DTR and both monthly rainfall and number of rainy days per month are analysed. The study is also the first step of checking the possibility of using DTR as a significant parameter in the rainfall prediction process.

Studied area and data used

The studied area is in northern Thailand and covers 17 provinces, which is about one third (166.1 km^2) of the total area of Thailand, as shown in Fig. 1.

It is located between latitudes 14°56'17" to 20°27°'5" N and longitudes 97°20'38" to 101°47'31" E and is mainly characterized by a mountainous topography in a north-south direction.
The data used in this study are the meteorological data that have been collected by the Thai Meteorological Department (TMD). These data comprise daily maximum land-surface air temperature (T_{max}), daily minimum land-surface air temperature (T_{min}), number of rainy days per month (RD), and the amount of total monthly rainfall (TRF). The historical data from 19 Meteorological stations distributed in northern Thailand over the period of 1978 to 2007 are used in this study.

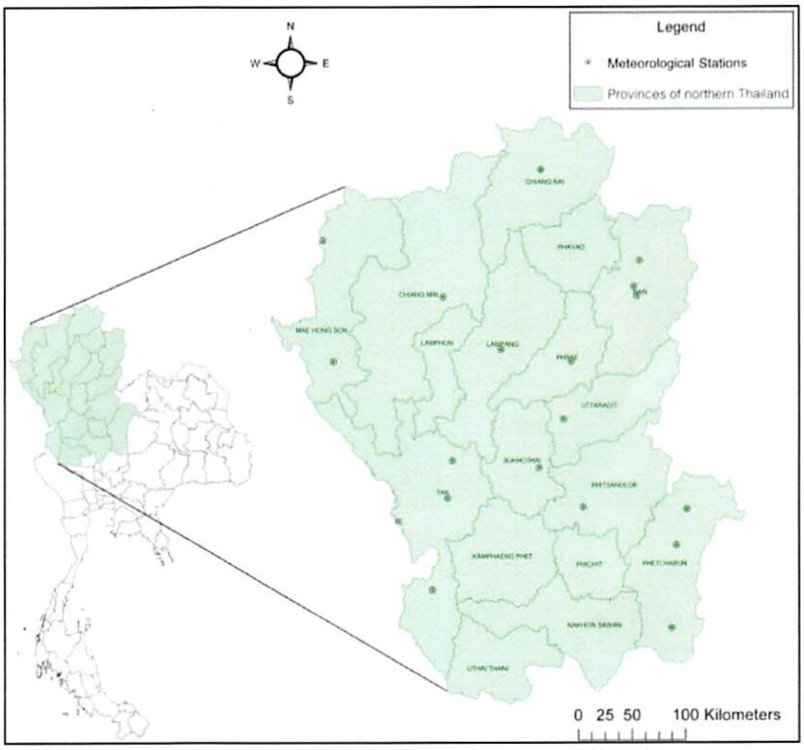

Figure 1. Studied area (northern Thailand)

Research Methodology

As the research focuses on temperature, the trend of changing Diurnal Temperature Range (DTR) has been observed by using the trend of a 10-year moving average. The mean monthly diurnal temperature range (DTR) can be obtained from the average DTR of the month. DTR can be calculated from daily temperature, as shown in equation (Eq.1).

$$DTR = T_{Max} - T_{Min} \quad \text{(Eq. 1)}$$

Where, T_{Max} is daily maximum land-surface air temperature, and T_{Min} is daily minimum land-surface air temperature. The data contains 30 years (1978-2007) of DTR, RD, and TRF from 19 stations over the study area. There are some missing data over the period of the study, which is about 0.54% of the total data. Due to this, less than 1% of the total data, therefore, was neglected. These studied years are classified into 3 groups of wet, normal, and dry years. The classification is done by comparing the amount of annual rainfall with the mean of annual rainfall over the studied years. The year in which annual rainfall is within the range of mean annual rainfall ± (0.5 × STD) is classified as a normal year. STD means standard deviation of the whole data. Those years for which annual rainfall is ≤ (0.5× STD) are classified as dry years, whereas years of annual rainfall ≥ (0.5 × STD) are classified as wet years. The impact of DTR on rainfall over the studied area is evaluated from the relationship between mean monthly DTR and TRF, as well as means monthly DTR and RD. Besides, the relationships of RD, TRF, and the temperature of mean monthly T_{max} and T_{min} are also analysed.

The significance of the correlation between the two parameters is identified by the coefficient of correlation (r). The value of the correlation coefficient (r) can be calculated by equation (Eq. 2).

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\sum_{i=1}^{n}(y_i-\bar{y})^2}} \qquad \text{(Eq. 2)}$$

Where, x_i and y_i are the considering parameters, and $\bar{x}$, $\bar{y}$ are mean values of those parameters. The higher absolute value of r indicates more correlation between two parameters. The obtained correlation coefficients of each case are shown in Table 1. In order to evaluate the possibility of applying DTR for prediction purposes, the analysis of correlation between mean monthly DTR and RD as well as TRF, with a month-lag time, has been done.

Results and Discussion

The global trend of the 10 year-moving average of DTR shows a decrease from 1900 to 1987, and since then it shows a rise in the trend [6]. Fig. 2 shows the trend of the 10-year moving average of the annual DTR over the studied area and demonstrates that the progression of the DTR is neither similar for all of studied stations nor similar to the global trend. These differences in the trends lead to the conclusion that the 10 year moving average of annual DTR over the studied area is mostly influenced by rather local circumstances, e.g., land use/cover, urban heat, soil moisture, cloud cover, and precipitation than supra-regional effects.

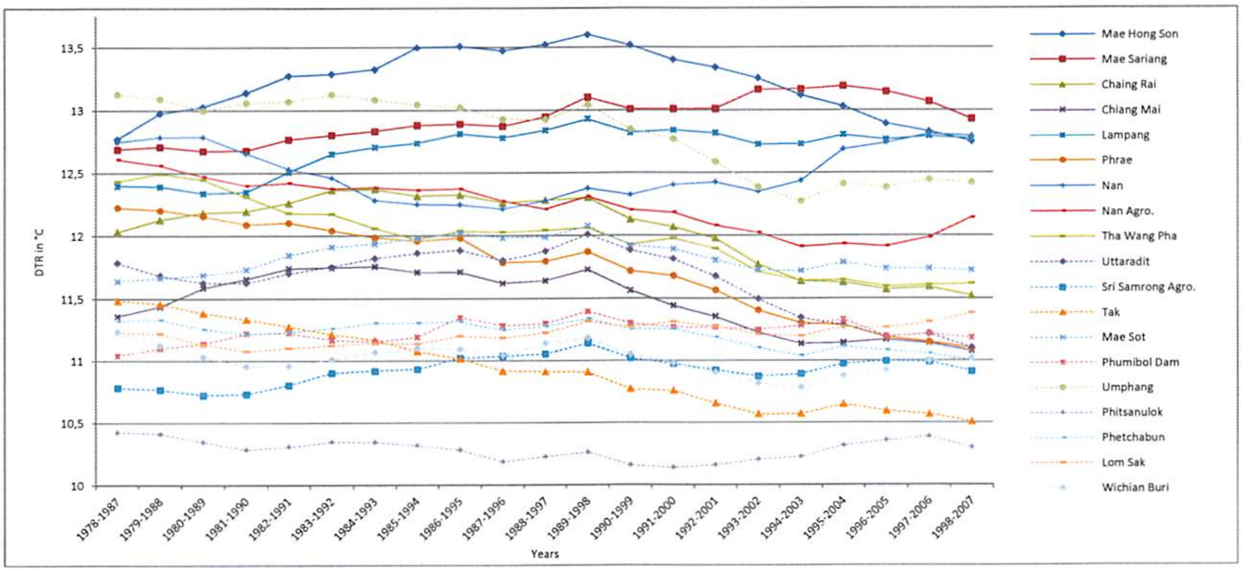

Figure 2. Trend of 10-year moving average of the annual DTR for each station from 1978 to 2007

In order to analyse the impact of DTR and temperature on rainfall, the correlations have been determined, as shown in Table 1 (a). The coefficients of correlation (r) indicate a strong correlation between mean monthly DTR and RD, as well as mean monthly DTR and TRF. In case of the mean monthly DTR and RD correlation, r ranges between -0.69 and -0.72 (statistical significance > 99%). For the mean monthly DTR and TRF, r ranges between -0.81 and -0.83 (statistical significance > 99%). Both show that the DTR has a strong statistically significant (> 99%) negative correlation with the RD and the TRF in all types of years. Mean monthly T_{min} has a stronger correlation with RD and TRF than mean monthly T_{max}. The coefficients of correlation obtained from mean monthly T_{max} with RD and TRF are very low. The coefficients of correlation of mean monthly T_{min} and RD are 0.67, 0.67, and 0.70 for dry, normal, and wet year, respectively. Whereas, r obtained from mean monthly T_{min} and TRF are slightly lower than RD: 0.56, 0.60, and 0.61 for dry, normal, and wet year, respectively.

In order to evaluate the possibility to predict rainfall using DTR, the correlation for a month-lag time has been considered by adding a lag time of one month to TRF and RD, as shown in Table 1 (b). For the TRF case, it leads to a decrease in the absolute value of r, of which the decrease ranges between 0.13 and 0.15, with the statistical significance > 99%. On the other hand, in the RD case, it leads to an increase in the absolute value of r, of which the decrease ranges between 0.8 and 0.9, with the statistical significance > 99%. Considering the lag-time case, the correlation of mean monthly DTR and TRF declines while the correlation of mean monthly DTR and RD improves.

Table 1. Coefficient of correlation (r) of DTR, T_{max}, T_{min} and RD, and DTR, T_{max}, T_{min} and TRF in dry, normal, and wet years for (a) monthly data and (b) monthly data with 1-month lag time (Statistical significance level ≥ 99%).

Coefficient of correlation between	(a) Monthly data			(b) Monthly data with 1-month lag time		
	Dry Year	Normal Year	Wet Year	Dry Year	Normal Year	Wet Year
DTR and RD	-0.69	-0.70	-0.72	-0.78	-0.78	-0.80
DTR and TRF	-0.82	-0.81	-0.83	-0.67	-0.68	-0.70
T_{max} and RD	-0.12	-0.16	-0.17	-0.35	-0.37	-0.36
T_{max} andTRF	-0.09	-0.10	-0.14	-0.30	-0.29	-0.28
T_{min} and RD	0.67	0.67	0.70	0.48	0.50	0.55
T_{min} and TRF	0.58	0.60	0.61	0.42	0.46	0.50

Conclusion

This study considers long-term monthly data over 30 years for DTR, RD, and TRF. The mean monthly DTR of the land-surface air temperature has a strong statistically significant (> 99%) negative correlation with the number of rainy days/month and the amount of monthly rainfall. It is concluded that monthly rainfall is changing inversely with the mean monthly DTR, which agrees with previous studies [7,11,12].

One month-lag time for the RD and TRF shows that the coefficient of correlation still indicates a strong statistically significant (> 99%) negative correlation between mean monthly DTR and RD, and DTR and TRF. Therefore, it is possible to consider DTR as a significant parameter for rainfall prediction. The coefficients of correlation of temperature and rainfall are lower than those of mean monthly DTR. It becomes apparent that the mean monthly DTR is more applicable than mean monthly T_{max} and T_{min}.

In summary, the DTR has a strong correlation with rainfall and shows a potential to be a significant parameter for rainfall prediction. Future studies should be done by applying the parameter of DTR in the rainfall prediction process.

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