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Trend discussion and analysis of diurnal temperature range
—Take Mingdao High School from 2018 to 2021 for example

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Abstract

Since 1950, the diurnal temperature range (DTR) of the monthly mean temperature in most parts of the world has been decreasing, which shows the phenomenon of climate change under global warming, and also affects many meteorological parameters. Starting from Mingdao High School and based on GLOBE PROGRAM, the purpose of this study is to explore the long-term trend of DTR in Mingdao and the possible factors that affect DTR, and further propose feasible measures to improve the measuring station of Mingdao. In this study, 11 meteorological parameters were selected and analyzed by univariate analysis and multivariate analysis. The results show that from 2018 to 2021 at Mingdao weather station, the DTR in spring, autumn and winter all showed a downward trend, mainly due to the increase in the average daily minimum temperature. In the rest of Taiwan weather stations, DTR is mainly related to the mean sunshine hours, mean relative humidity and mean daily maximum temperature.

Research Questions and Hypothesis

1. Research motivation

Weather and climate are intertwined by a variety of different weather factors. Among the various meteorological parameters, the temperature is of particular interest to us, and the temperature can often reflect the changes of the climate. In recent years, there have been more studies on the monthly average maximum temperature and monthly average minimum temperature, while there are relatively few studies on the daily range of monthly average temperature. However, DTR is very important for people to understand local weather patterns, man-made disturbances, and the change of seasons.

Mingdao High School joined THE GLOBE PROGRAM in 2018. The observations include air temperature, soil temperature and relative humidity, etc. So far, there are a large number of unconsolidated observation data. As a member of GLOBE PROGRAM, we decided to take DTR as the starting point and take the data of Mingdao High School as the research object (2018 to 2021), and analyze the trend changes, and try to find out the relevant possible factors that affect DTR.

2. Literature review

In recent years, the DTR in various regions of the world has continued to decline (David R. Easterling et al., 1997; Karl Braganza et al., 2004). From 1950 to 2004, the amplitude of global minimum temperature rise was two times more than that of maximum temperature, resulting in a substantial decrease in DTR (Russell S. Vose et al., 2005). Lai Liwei and Jiang Shanxin (2004) found that the monthly average DTR of most stations in the four seasons in Taiwan showed a significant decreasing trend, which was mainly due to a significant upward trend in the monthly average minimum temperature, especially in autumn (Aiguo Dai et al. al., 1999). Yao Minghui et al. analyzed the temperature trend in Taichung in the past 40 years (1960-1999) and found that the average temperature increased by 0.86°C, the average maximum temperature decreased by 0.41°C, and the average minimum temperature increased significantly by 1.66°C, resulting in a significant decrease in DTR.

The reduction of average DTR is negatively correlated with cloud cover (Karl et al., 1993). In addition, the height and type of clouds will determine the degree of reflected sunlight, which in turn affects DTR. Low-etage clouds have the best effect on reducing DTR (Aiguo Dai et al., 1999). On the other hand, humidity has little effect on the average DTR (Aiguo Dai et al., 1999)
DTR is highly correlated with sunshine length and sunshine rate (Deepak Jhajharia, Vijay P. Singh, 2011). The decrease in sunshine length directly reduces the average maximum temperature, which in turn reduces the average DTR (Xiangjin Shen et al., 2014). Another study found that greenhouse gases and sulfate aerosols (sulphate aerosols) will lead to a small decline in global DTR (Dai et al., 2001; Stone and Weaver, 2002, 2003). According to the analysis of radiative-convective model, when the concentration of carbon dioxide and tropospheric aerosol increases by 50%, the DTR will show a decreasing trend (Stenchikov and Robock, 1995). There was a certain degree of negative correlation with DTR.

On the other hand, human interference factors and natural disasters will also have a certain degree of impact on DTR. Among the human interference factors, take Taichung air pollution (total PM2.5 content) as an example. According to the statistics of the past years, it is not difficult to find that the total amount of PM2.5 has shown a downward trend since 2014, but has increased in 2020. This is caused by the large amount of coal burning in thermal power plants. However, regardless of the trend, the air quality in Taichung area It is still very poor. In addition, serious air pollution in mainland China will also drift to Taiwan due to the monsoon wind direction, especially in winter. Among natural disasters, typhoons in the waters adjacent to Taiwan are more common in summer (around July to September), and the probability of invading Taiwan is also high. Such as No. 201808 Severe Typhoon (MARIA; July 11, 2018, Typhoon Database—Central Weather Bureau; CWB)

In addition, greenhouse gases, including carbon dioxide, methane, nitrous oxide, etc., are closely related to global warming, and will also indirectly have a considerable impact on DTR. Carbon dioxide has a big impact. Since the record began in 1958, the global carbon dioxide concentration has been increasing year by year. In May 2019, carbon dioxide reached 415.26 ppm, the highest in history. This is caused by the massive burning of fossil fuels. This phenomenon will exacerbate the Greenhouse effect, which in turn will lead to an increase in global temperature. According to data from the World Meteorological Organization (WMO), the temperature on the earth is now nearly 1°C higher than before industrialization began to spread. According to this trend, the global temperature will be 3-5°C higher than the pre-industrial level by 2100. Temperature will affect other meteorological parameters, leading to long-term large-scale changes in weather patterns and climates in various regions of the world.

To sum up, it is not difficult to find that DTR is highly correlated with the daily mean temperature (Ta), the daily maximum temperature (Tmax), and the daily minimum temperature (Tmin), as well as the cloud cover (CC), daily sunshine duration (SH), daily global radiation (GR), greenhouse gas content, mean aerosol content (AC), The mean wind speed (WS) has a certain proportional correlation, and among the daily mean cloud cover, the mean low cloud cover (LCC) is particularly influential. Interestingly, the change of mean relative humidity (RH) has little effect on DTR, while the effect of mean atmospheric pressure (Pa) on DTR has not been found in the literature so far. , we still assume the likelihood of its impact. Below, we will summarize and list the parameters to be selected based on the above literature results, and compare and analyze them item by item.

3.Research questions

1) What's the long-term trend of DTR in Mingdao?
2) What's the correlation of factors that affect DTR?
3) What's the different of DTR between Mingdao and other weather stations in Taiwan?

Materials and Method

1. Research structure

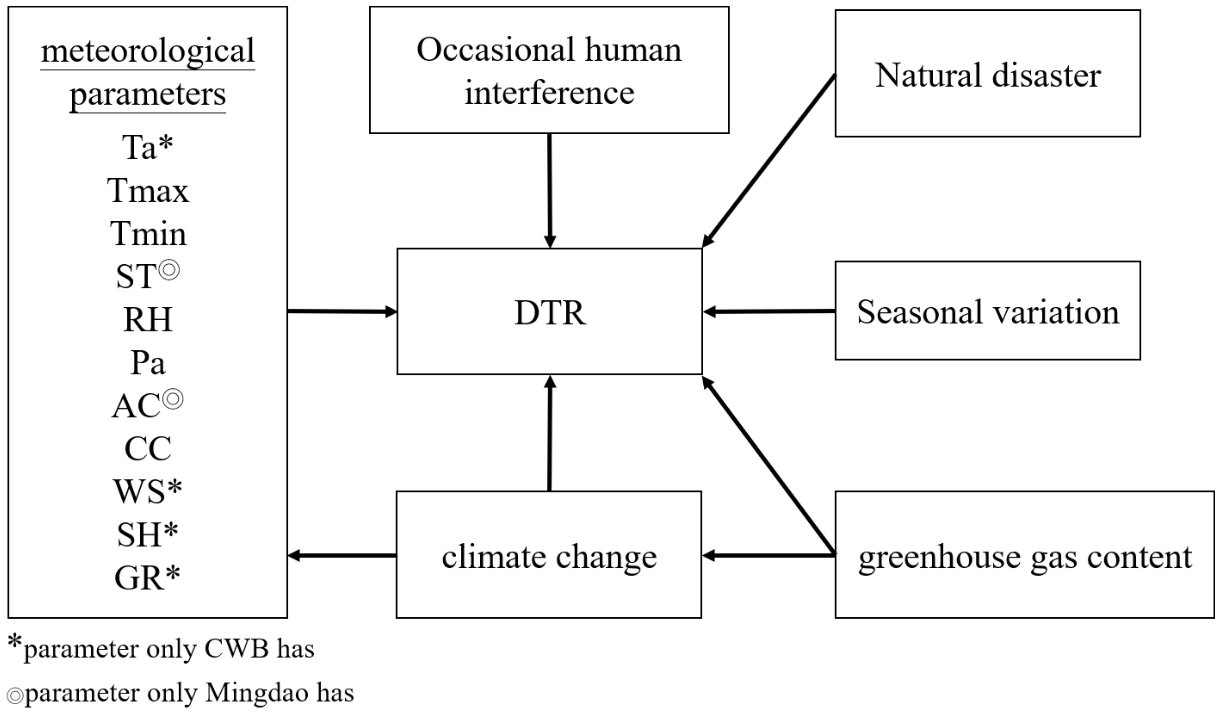

Fig.1. Research structure (Factors related to DTR)

The structure of this study, with DTR as the center, focuses on the related factors that affect DTR. Through the above literature discussion, we try our best to list the meteorological parameters that are easier to observe and have greater influence, and further regard them as the variable items (Ta, Tmax, Tmin, etc.) of this study. In addition, we have also summarized many external factors with a long time and a large range to facilitate the analysis of the results in the future.

2. Research steps

1) Research process

Based on the GLOBE Program, this research uses the data observed by Mingdao students to figure out the value of the research, and then confirm the research purpose. In order to make the background information of the study more sufficient, we conducted a series of literature review and discussion as evidence of the experimental results. By reviewing the previous literature, we have integrated many better and referenced research methods, so that the results can be presented more accurately. Then, the paper data of Mingdao station and the data from 2018 to 2021 of CWB were input and compiled, and calculated by statistical methods for cross-validation. Finally, after merging and grouping the multiple data, we analyze the result chart year by year. According to the literature, we guess and analyze the possible factors behind the data, summarize the relevant characteristics of DTR, and give conclusions and appropriate suggestions.

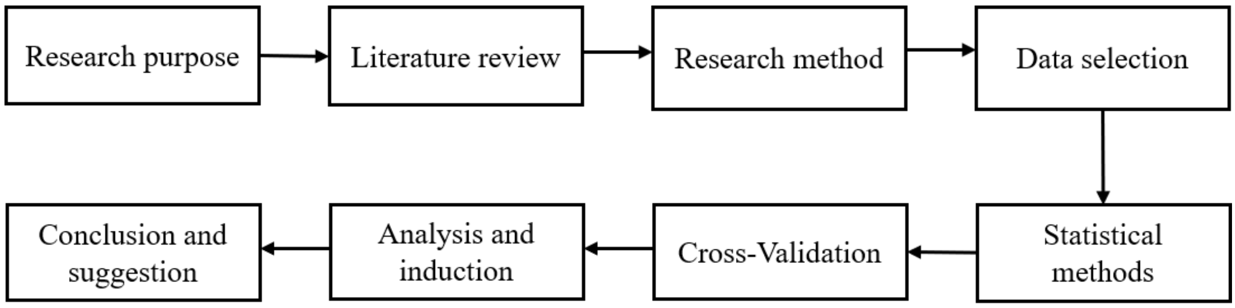

Fig. 2. Research flowchart-1

2) Data selection process

In the process of data selection, we found that some meteorological parameters were observed by the CWB but not at Mingdao Station; there were also a small number of parameters that Mingdao Middle School had, but the CWB lacked. In order to solve this problem, this study determined a series of comparison methods was developed and divided into three groups in total. The first group is the internal analysis of Mingdao station, that is, only the data of Mingdao is used. The second group represents the comparison between Mingdao station and the station in the region of middle Taiwan from the CWB (Group B). Only the region of middle Taiwan is selected because Mingdao High School is also located in the middle of Taiwan. Selecting similar areas can reduce the impact of geography and climate. The third group excludes Mingdao station, and only four groups A, B, C, and D of the CWB are compared, reflecting the impact of different regions on DTR under the same observation method and time.

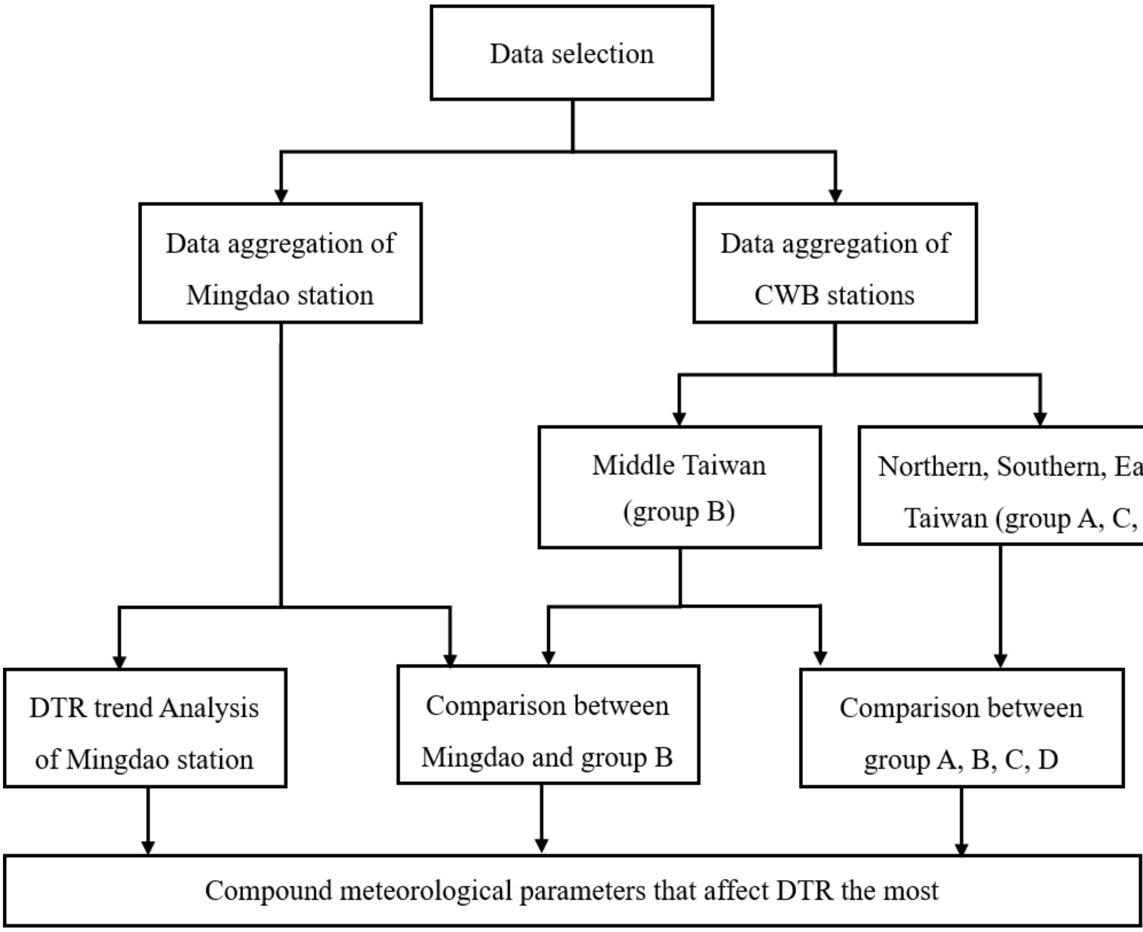

Fig. 3. Research flowchart-2

3. Data collection and selection:

1) The measure of Mingdao station

The data observation and recording of Mingdao station adopts the methods and standards of the GLOBE Program, and the observation is carried out at 12:50 noon. This study selects observational data (a) daily maximum temperature (b) daily minimum temperature (c) current relative humidity (d) current air pressure (e) current sky visibility (f) current cloud coverage. Among them, due to instruments and other factors, the four parameters of relative humidity, air pressure, visibility, and cloud coverage are only the "current values" observed at 12:50, not the average of one day. Although they cannot fully reflect the real situation, there is still some value in them, so it is also included in the data. Details are listed below:

a) Daily maximum temperature: measured with a digital thermometer and placed in a louvered box. Record the highest daily temperature from 12:50 noon the previous day to 12:50 today.

b) Daily minimum temperature: measured with a digital thermometer and placed in a louvered box. Record the Lowest daily temperature from 12:50 noon the previous day to 12:50 today.

c) Current relative humidity (current RH): measured with a digital hygrometer and placed in a louvered box. In addition, if there is precipitation during the observation, it will be counted as 100%.

d) Current air pressure (current P): measured with a sea level station barometer.

e) Current sky visibility: From the corridor outside the Science Office (4th floor), the line of sight is parallel to the ground (elevation angle 0°), and the visibility of the mountains in the distance is directly east. According to the standards set by GLOBE, there are five categories: Unusually Clear, Clear, Somewhat Hazy, Very Hazy and Extremely Hazy. Considering that the original observation results are not quantified, and in order to match the data standard of the CWB(usually counted as 0-10), this study has customized the numbering standard: unusually clear = 0, clear = 2, slightly hazy = 4, very haze = 7 and extreme haze = 10. In addition, "Cannot Observed" is calculated as N/A. Since there is no Sun Photometer installed at Mingdao station, it is impossible to estimate the aerosol content of the day in a more accurate way. Therefore, this study decided to use "sky visibility" to represent the near-surface sky profile. Hope to indirectly reflect the aerosol content (AC).

f) Current cloud cover (Current CC): The percentage of the sky covered by clouds. Looking up from the corridor outside the Science Office (fourth floor) and calculation visually. According to GLOBE's standards, it is divided into six categories: No Clouds (0%), Clear (Clear, >0 to 10%), Isolated (10 to 25%), Scattered (Scattered, 25%) to 50%), Broken (Broken, 50 to 90%) and Cloudy (Overcast, >90%). We also have customized the numbering standard in the study (for the same reasons as above 6.).

2) Other regions (From CWB)

In order to obtain a suitable analogy for Mingdao station, this study selected the meteorological parameters from 2018 to 2021 of the "CWB Observation Data Query Network" to verify the degree of agreement with the data in other regions. Meteorological parameters selection: (a) station pressure, (b) relative humidity, (c) average temperature, (d) daily maximum temperature, (e) daily minimum temperature, (f) cloud coverage, (g) average wind speed, (h) sunshine hours, (i) total sky insolation. In addition, this study also selects three meteorological parameters that are not observed at Mingdao station, but are very important to the impact of DTR, namely (g), (h), (i).

This study takes Taiwan as the main body, and divides Taiwan into four regions: northern, central, southern, and eastern. A total of four stations are selected for research in each region to reflect the long-term climate type and the year-by-year change trend of related meteorological parameters. The following codes are used to indicate them: A (North), B (Central), C (South), D (East). The list of selected station geographic information is as follows:

TABLE 1. The information of weather stations selected in Taiwan (From Central Meteorological Administration, Government Data Open Platform)

Group	Name of weather station	North latitude	East longitude	Altitude(m)	Time span (year)
A	Hsinchu	24.8278	121.0142	26.9	2018 to 2021
	Taipei	25.0376	121.5148	5.3	2018 to 2021
	Tamsui	25.1648	121.4489	19.0	2018 to 2021
	Banqiao	24.9976	121.4420	9.7	2018 to 2021
B	Wuqi	24.2560	120.5233	31.73	2018 to 2021
	Taichung	24.1457	120.6840	84.04	2018 to 2021
	Chiayi	23.4959	120.4329	26.9	2018 to 2021
C	Yongkang	23.0383	120.2367	8.1	2018 to 2021
	Tainan	22.9932	120.2047	40.8	2018 to 2021
	Kaohsiung	22.5659	120.3157	2.3	2018 to 2021
	Hengchun	22.0038	120.7463	22.3	2018 to 2021
D	Taitung	22.7522	121.1545	9.0	2018 to 2021
	Chenggong	23.0974	121.3734	33.5	2018 to 2021
	Hualien	23.9751	121.6132	16.1	2018 to 2021
	Su'ao	24.5967	121.8573	24.9	2018 to 2021

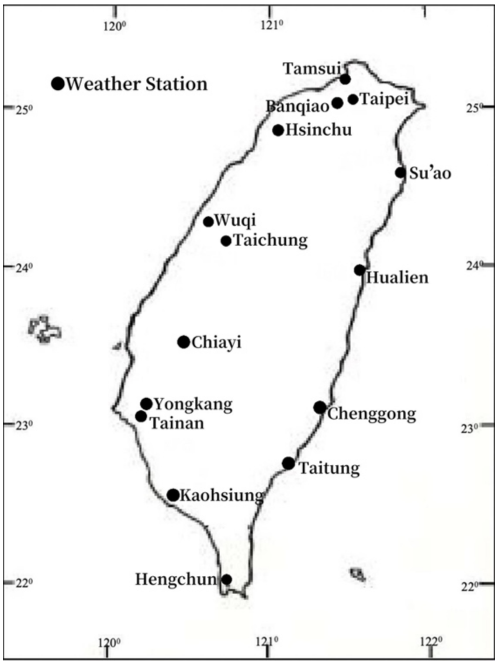

Fig. 4. Location of each weather station.

4. Data process

1) Classification method

In the data of Mingdao station, this study classified the DTR into four seasons: spring is March, April, May; summer is June, July, August; autumn is September, October, November; winter is December, January, February. Due to the unstable environment, the DTR fluctuates greatly day by day, so the average value of DTR in the year is used as a trend chart. Then, the other meteorological parameters are compared with the DTR, and the scatter diagram shows the relationship. The information from the Central Meteorological Administration is also classified as above.

2) Deviation exclusion

Due to the short observation time, and considering the deviation caused by the students' measurement errors, human disturbance, and short-term unstable weather factors, this study uses Microsoft Excel to detect outliers, and confirms that the data is normally distributed before calculating Lower quartile (Q1), Upper quartile (Q3), and interquartile range (IQR). If the data is outside the range of Q1 - 1.5 * IQR to Q3 + 1.5 * IQR, it is very likely to represent the data with large deviation or problems which should be deleted.

3) Some missing data

From June to the end of August 2021, the school was closed due to the epidemic, and most students couldn’t come school to do observation, resulting in an extremely insufficient amount of data in the summer of 2021. After meticulous discussion, in order to avoid distortion of the average value, we decided to abandon this section of data.

4) Statistical methods

This study uses the SAS 9.4 version system to carry out the following statistical methods.

a) Univariate analysis:

$$Y=\alpha 0+\beta X$$

The independent variables (X) we choose are all parameters except DTR, and the dependent variables (Y) are all DTR.

$$\beta = e^{\text{estimate of parameter}}$$

After univariate analysis is carried out for the variables one by one, the estimated of parameter can be obtained, and the correlation between the variable and the DTR can be known. We also output scatter diagram so that future trends can be predicted. In addition, in order to test the rationality of the results, under the premise of the null hypothesis (H0) and the normal distribution, the rationality of the hypothesis is determined according to the size of the P value.

b) Multivariate analysis:

$$Y = \alpha 0 + \beta 1 X1 + \beta 2 X2 + \beta 3 X3 \ldots$$

The independent variables (X) are all parameters except DTR, and the dependent variables (Y) are all DTR. The estimation method of multivariate analysis is the same as univariate analysis.

Results and Discussion

1. Trend Analysis

Considering the degree of influence of seasonal transformation factors on different parameters, the following is a discussion of the results of the four seasons.

1) Mingdao station

In spring, the DTR has a downward trend year by year, and is slightly flat (about 0.3-0.5 degrees per year) in 2021. In 2018 and 2019, the daily minimum temperature rise was larger than the daily maximum temperature; in 2020, the daily maximum temperature and the daily minimum temperature curve were similar; in 2021, the daily maximum temperature changed more than the daily minimum temperature.

In summer, it first dropped to the lowest point (about 6 degrees) and then rose since 2018. In 2018, the daily maximum temperature and daily minimum temperature fluctuated in the same range, while in 2019 and 2020, the DTR was mainly due to the large fluctuation of the daily minimum temperature.

In autumn and winter, the downward trend of DTR is very similar, and it will be slightly flattened by 2021 (about 0.3-0.5 degrees per year). The daily minimum temperature is similar to the daily maximum temperature curvature.

Overall, in the short-term results from 2018 to 2021, we find that the DTR trend is decreasing in spring, autumn and winter, and the degree is very similar. In addition, the trend fluctuation of the daily maximum temperature and the daily minimum temperature height in the Mingdao station in four years is similar to that of the daily minimum temperature height. It is worth noting that in most of the time, the DTR is more affected by the daily minimum temperature than the daily maximum temperature.

a) The downward trend of the overall DTR is the same as that of most research literatures. We conjecture that global warming may be a very critical factor, and the increase in average temperature and daily minimum temperature has a significant impact on DTR.

b) DTR≧9℃

Because Taiwan is located in the subtropical zone and has an island-type climate, when the daily temperature difference is too large, people often feel uncomfortable. There is no clear definition of what constitutes a large daily temperature difference, but this study defines it as the average of Taiwan's 50-year DTR (about 7°C) plus 2°C, or 9°C. After statistics, a total of 21 records (2018: 9, 2019: 4, 2020: 1, 2021: 7), fifteen of which occurred in the late autumn and early winter (November, December, January) , we speculate that it is due to the continuous southward movement of the Continental Polar cold air mass (cP), the daily minimum temperature drops sharply, and the DTR increases.

2) Comparison with the station in the region of middle Taiwan

Looking at Fig. 5. to Fig. 8., we find that the DTR in Mingdao station is similar in Wuqi (both between 5°C and 7.5°C), while the Taichung and Chiayi stations are much higher than those in Mingdao (both between 7°C and 11°C).). From the perspective of seasons, Wuqi Station has little fluctuations in the four seasons, while the difference between Taichung and Chiayi is quite significant. The DTR in summer is the lowest, to a certain extent, it is the same as that of Mingdao in 2018 and 2019, and the DTR in winter is the largest. Perhaps due to the short period of time, the influence of many environmental instability factors has become greater, resulting in a less obvious year-on-year decline in the overall DTR, and there are irregular fluctuations from time to time, such as: winter in Wuqi in 2019 and spring in Taichung , Chiayi's spring has a considerable rise and fall (about 1°C difference); Chiayi's summer suddenly rises in 2020, etc. As far as the middle region of Taiwan is concerned, however, most do show a declining or stable trend.

Based on the above results, we infer that the trend of DTR from 2018 to 2021 is mainly due to the regional local warming caused by the urban heat island effect. This is due to the excessive concentration of exhaust gas and dense population in the city. We found that the four stations in the middle region of Taiwan are all located in the area of moderate to high heat island effect intensity. Therefore, it is not difficult to understand that the increase of the overall temperature (the degree is also Tmin>Tmax) causes the DTR to gradually decrease or remain unchanged.

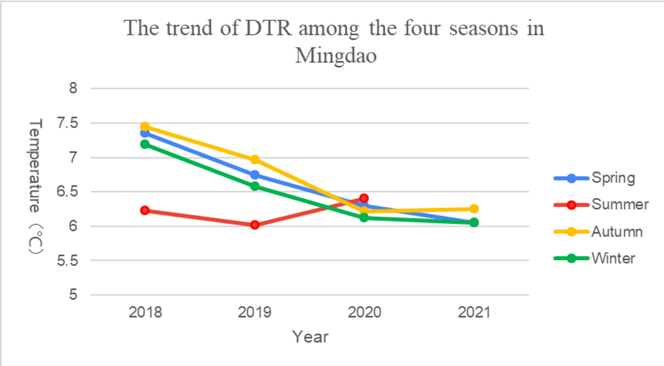

Fig. 5. The trend of DTR among the four seasons in Mingdao.

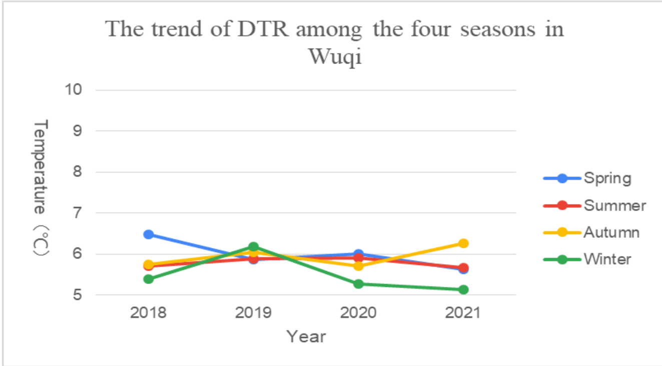

Fig. 6. The trend of DTR among the four seasons in Wuqi.

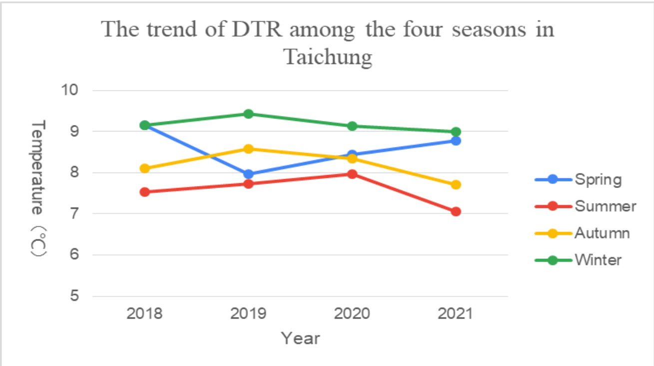

Fig. 7. The trend of DTR among the four seasons in Taichung.

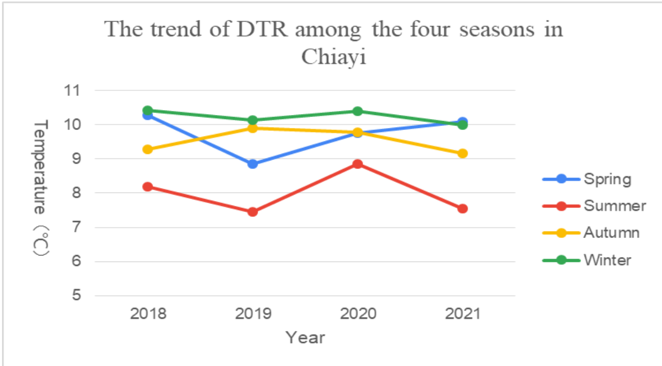

Fig. 8. The trend of DTR among the four seasons in Chiayi.

2. Factors related to DTR

1) Mingdao Station

In the univariate analysis, it is not difficult to find that the correlations (β) of the six independent variables and DTR are all between 0.8 and 1.0, among which the P values of Tmax, current air pressure and current visibility are all greater than 0.05, which is considered to be less related to DTR. Therefore, this study first excluded these three independent variables. Then, multivariate analysis was performed on Tmin, current RH, and current CC. The results showed that all three were negatively correlated with DTR (estimate of parameter value < 0) and were highly correlated. However, there was no significant correlation between current CC and DTR probably due to multiple variables (P > 0.05).

From the analysis results, we found that the P value of the current CC is larger than the other two, which means that it is not the most important component of the DTR, but the negative correlation results are still consistent with previous studies. On the other hand, Tmin is the most influential main component among the three (P<0.0001), and the correlation is very high (also negative correlation), which is in line with the literature "The decrease in monthly average DTR over the years is mainly due to the significant upward trend of monthly average Tmin." It is worth noting that the current RH and DTR are significantly negatively correlated (the proportion of components is in the middle), which is contrary to the literature that "DTR has no correlation with relative humidity" or has a high positive correlation (Huang Yanyi, Weng Shuping, 2011). We speculate that it is because humidity can decrease the range of temperature and cause this result in the area near the Mingdao region.

Table 2. Univariate analysis of Mingdao station.

independent variables	estimate of parameter	β	standard error	P value
Tmin	-0.17610	0.83853	0.02612	<0.0001
Tmax	0.01329	1.0134	0.03128	0.6714
Current P	0.02976	1.0302	0.01827	0.1047
Current RH	-0.02313	0.97713	0.00708	0.0013
Current sky visibility	-0.00976	0.99029	0.06096	0.8729
Current CC	-0.10722	0.89832	0.04021	0.0082

Note: The double bottom line indicates that the β value is significantly larger and the p-value is within a reasonable range (P≦0.01).

Table 3. Multivariate analysis of Mingdao station.

independent variables	estimate of parameter	β	standard error	P value
Tmin	-0.16525	0.84776	0.02689	<0.0001
Current RH	-0.01486	0.98524	0.00750	0.0486
Current CC	-0.01901	0.98117	0.04164	0.6485

Note: The single bottom line indicates a high correlation with DTR.

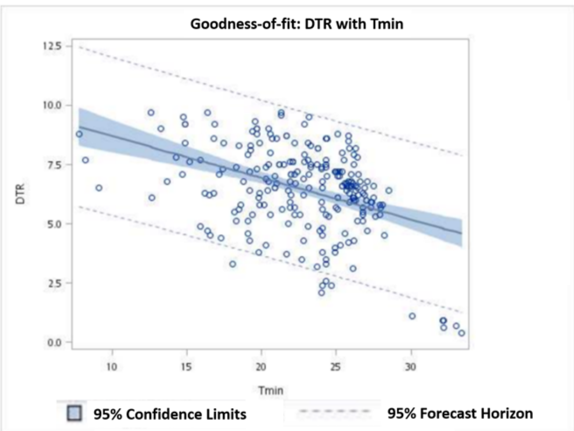

Fig. 9. The relation between Tmin and DTR.

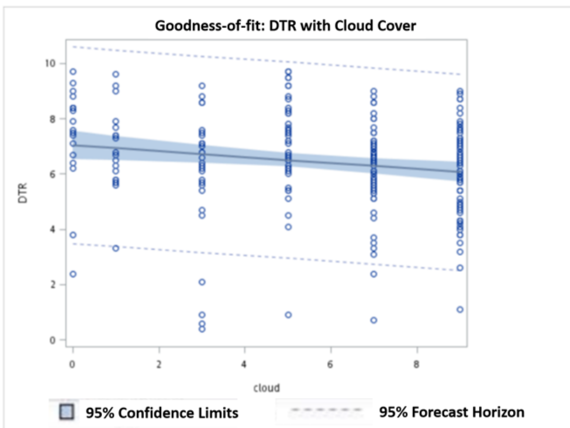

Fig. 10. The relation between CC and DTR

2) The station of CWB

Table 4. Univariate analysis of northern Taiwan stations (group A).

independent variables	estimate of parameter	β	standard error	P value
Ta	0.10692	1.11285	0.01618	<0.0001
Tmin	0.06793	1.07029	0.01346	<0.0001
Tmax	0.16456	1.17887	0.01909	<0.0001
Pa	-0.08900	0.91485	0.01309	<0.0001
RH	-0.12255	0.88466	0.01542	<0.0001
WS	-0.84163	0.43101	0.15696	<0.0001
CC	-0.36480	0.69434	0.10073	0.0004
SH	0.01140	1.01147	0.00130	<0.0001
GR	0.00443	1.00444	0.00050	<0.0001

Note: The double bottom line indicates that the β value is significantly larger and the P value is within a reasonable range ($P \leqq 0.01$). The following four groups of ABCD are based on this standard.

Table 5. Multivariate analysis of northern Taiwan stations (group A).

independent variables	estimate of parameter	β	standard error	P value
Ta	0.07117	1.07376	0.07359	0.3348
Tmin	-0.22354	0.79968	0.04393	<0.0001
Tmax	0.23428	1.26998	0.04191	<0.0001
Pa	-0.03042	0.97004	0.02821	0.2822
RH	-0.04625	0.95480	0.01521	0.0027
SH	0.00668	1.00670	0.00216	0.0024
GR	0.00107	1.00107	0.00092	0.2466

Note: The single bottom line indicates a high correlation with DTR.

In the data of group A, after the univariate analysis, we deleted the independent variables with low correlation of WS and CC, and started the multivariate analysis. In the results of the northern station, the independent variables with significant principal components are: Tmin, Tmax, RH, SH, while Ta, Pa, and GR, which have no obvious correlation with DTR, are not included in the discussion. Among them, the influence of Tmax on DTR was greater than that of Tmin, RH was highly negatively correlated with DTR, and SH was highly positively correlated with DTR.

Table 6. Univariate analysis of middle Taiwan stations (group B).

independent variables	estimate of parameter	β	standard error	P value
Ta	-0.05672	0.94486	0.03376	0.0952
Tmin	-0.08419	0.91926	0.02472	0.0009
Tmax	0.13779	1.14773	0.04450	0.0024
Pa	0.02014	1.02034	0.02510	0.4239
RH	-0.09015	0.91379	0.03952	0.0241
WS	-0.88956	0.41084	0.06585	<0.0001
CC	-0.43730	0.64577	0.11472	0.0002
SH	0.00462	1.00463	0.00358	0.1990
GR	0.00195	1.00195	0.00138	0.1610

Table 7. Multivariate analysis of middle Taiwan stations (group B).

independent variables	estimate of parameter	β	standard error	P value
Tmin	-0.35753	0.69940	0.02501	<0.0001
Tmax	0.63201	1.88139	0.04471	<0.0001

In the data of group B, after univariate analysis, only Tmin and Tmax were retained in multivariate analysis due to the low correlation of most variables ($P \geqq 0.01$). In the results of the central station, both are highly correlated with DTR, Tmin is negatively correlated, and Tmax is positively correlated. It is worth noting that Tmax still accounts for more principal components than Tmin, almost three times more than that of Tmin.

Table 8. Univariate analysis of southern Taiwan stations (group C).

independent variables	estimate of parameter	β	standard error	P value
Ta	-0.21772	0.80435	0.02253	<0.0001
Tmin	-0.17161	0.84231	0.01487	<0.0001
Tmax	-0.15904	0.85296	0.04201	0.0002
Pa	0.13766	1.1476	0.01816	<0.0001
RH	-0.08117	0.92203	0.01922	<0.0001
WS	-0.00191	0.99801	0.13028	0.9883
CC	-0.37056	0.69034	0.06708	<0.0001
SH	0.00671	1.00673	0.00200	0.0010
GR	-0.00124	0.99876	0.00094	0.1899

Table 9. Multivariate analysis of southern Taiwan stations (group C).

independent variables	estimate of parameter	β	standard error	P value
Ta	-0.33624	0.71445	0.09214	0.0003
Tmin	-0.15982	0.85230	0.05341	0.0032
Tmax	0.56511	1.75964	0.05678	<0.0001
Pa	-0.00028	0.99972	0.02810	0.9920
RH	0.02795	1.02834	0.01627	0.0875
SH	0.00823	1.00826	0.00141	<0.0001

In the data of group C, after univariate analysis, we deleted the variables with low correlation of WS, CC, and GR, and started multivariate analysis. In the results of the southern station, the variables with significant principal components are: Ta, Tmin, Tmax, SH. The influence of Tmax on DTR is still larger than that of Tmin; SH has a highly positive correlation with DTR, while Ta has a moderately high negative correlation with DTR.

Table 10. Univariate analysis of eastern Taiwan stations (group D).

independent variables	estimate of parameter	β	standard error	P value
Ta	0.06959	1.07207	0.01335	<0.0001
Tmin	0.04432	1.04532	0.01051	<0.0001
Tmax	0.09717	1.10205	0.01611	<0.0001
Pa	-0.00043	0.99957	0.00021	0.0467
RH	-0.05412	0.94732	0.01185	<0.0001
WS	-0.07477	0.92796	0.07559	0.3239
CC	-0.31991	0.72621	0.03825	<0.0001
SH	0.00547	1.00548	0.00069	<0.0001
GR	0.00228	1.00228	0.00028	<0.0001

Table 11. Multivariate analysis of eastern Taiwan stations (group D).

independent variables	estimate of parameter	β	standard error	P value
Ta	-0.16173	0.85067	0.07469	0.0317
Tmin	-0.04576	0.95527	0.03967	0.2502
Tmax	0.18906	1.20811	0.04701	<0.0001
RH	-0.04056	0.96025	0.01005	<0.0001
SH	0.00468	1.00469	0.00179	0.00098
GR	0.00193	1.00193	0.00071	0.0074

In the data of group D, after univariate analysis, we deleted the variables with low correlations in Pa, WS, and CC, and started multivariate analysis. In the results of the eastern station, the variables with significant principal components are: Tmax, RH, SH, GR. The influence of Tmax on DTR was still the most significant, RH was highly negatively correlated with DTR, and SH was highly positively correlated with DTR. Interestingly, GR is only the dominant component in this group (highly positively correlated), and it is not difficult to understand that an increase in global radiation (GR) will increase the average Tmax, which in turn leads to an increase in the average DTR, perhaps this phenomenon It is more obvious in eastern Taiwan.

Based on the results above, the weather stations in the four regions of Taiwan are selected in this study, and we summarize the following characteristics: (a) The average sunshine hours (SH) are mostly highly positively correlated with DTR, which is consistent with the literature. The increase of the number will lead to the increase of Tmax, which will lead to the increase of DTR. (b) Tmax is highly positively correlated with DTR, while most of Tmin is highly negatively correlated with DTR, and the influence of Tmax is much larger than that of Tmin (about 2 to 3 times), however, this result obviously contradicts many literatures. Hence, we inference that because the average sunshine hours is a significant principal component, and the sunshine hours drive the increase of Tmax, so that Tmax can have a significant impact on DTR. On the other hand, perhaps for most stations, many environmental factors (eg, cloudy at night) make the radiative cooling of the surface less obvious at night in this area, so that Tmin is not easily reduced significantly. This situation is likely to allow the DTR, which has a small average amplitude, to be affected by Tmax, resulting in a high correlation. (c) The RH and DTR of some stations are highly negatively correlated, which is also inconsistent with many research results. It is speculated that the reason is roughly same as Mingdao station.

In the above results, we also concluded some meteorological parameters that have little correlation with DTR: (a) mean air pressure (Pa), which is consistent with the results of the literature. (b) Mean wind speed (WS), which is contrary to the literature that "wind speed is highly negatively correlated with DTR", is inferred to be caused by the uniqueness of different spatial regions. (c) the average cloud cover (CC), which is also inconsistent with the literature "cloud cover is negatively correlated with DTR." Perhaps it is because this study only counts the overall cloud cover, and most of the stations have relatively high atmospheric stability, which may result in the formation of high cloud etage or middle cloud etage, so the low etage cloud cover (LCC) with high influence components is ignored.

3. Discussion on the problem of Mingdao weather station.

1) Time-span isn’t long enough:

When analyzing problems with large time scales (such as climate change or the year-to-year trend of DTR), it is often difficult for us to make accurate and objective judgments because the number of samples is too small and the trend is not significant enough. Additionally, it also increases the probability of linear regression model predictions being distorted. However, we can find more details in the data and graphs than others because of this.

2) The overall data deviation is large:

When using Excel to detect outliers, the data we excluded accounted for about 17.3% of the total. The reasons for the deviation are as follows: (1) The old instruments cause deviations, (2) Some weather observations are subjective, so the standards of different students may be different. (3) There are only five classification for sky visibility and cloud cover according to the GLOBE Program standards, which makes the observation isn’t always absolutely correct in some particular situation.

3) Lack of average data:

Due to the limitations of school instrument, many meteorological parameters cannot record their average values and can only record the "current state". However, the observation time point of the students is the same (12:50 noon), which may reflect the atmospheric state during the day to some extent.

4) The observation frequency is unstable:

When collating the data, we found that because the observed students aren’t many at all and most of them are spontaneous. Therefore, the amount of data decrease intensely before the exams and during the summer (winter) vacation. Sometimes even only 6 times a month, which makes the average vulnerable to a few extreme values.

5) Future prospects:

In conclusion, we believe that it is very important to set more uniform standards for specific meteorological parameters observation in the future, and to regularly check and update old instruments to reduce the deviation rate. In addition, according to the results, sunshine hours (SH) and all-sky insolation (GR) do have a certain degree of influence on DTR. It is possible to consider setting up anemometers, solar photometers, etc. to complete the research. It is highly helpful for future research on other topics related to DTR.

Conclusions

1. In the results of Mingdao Station from 2018 to 2021, the DTR in spring, autumn and winter all showed a downward trend, and the degree was very similar. The days with larger DTR mainly occurred in the late autumn and early winter, presumably because the Continental Polar cold air mass (cP) moved southward, which results in the daily minimum temperature dropped sharply.
2. In comparison with other weather stations in middle Taiwan, the DTR of Mingdao station and

Wuqi station are similar. Overall, most of the middle regions showed a decreasing or stable trend, which was speculated to be caused by the urban heat island effect leading to regional local warming. Besides amplitude of Tmin was greater than or equal to Tmax.

3. Among the main factors of Mingdao station related to DTR, according to the P value, the degree of influence is Tmin > current humidity > current cloud cover, and they are all negatively correlated. The sharp increase in Tmin and the increase in cloud coverage lead to a decrease in DTR, which is consistent with the literature. On the other hand, the cloud cover is less obvious. The negative correlation between humidity and DTR contradicts the study, we thought that humidity can decrease the range of temperature.

4. In the comprehensive results of the main factors affecting DTR in the four regions of Taiwan, most of the average sunshine hours are highly positively correlated with DTR, while the average relative humidity of some stations is highly negatively correlated with DTR. It is worth noting that the influence of Tmax (positive correlation) is much larger than that of Tmin (negative correlation) (about 2 to 3 times). Yet, this result is obviously different from the literature. We speculate it is the radiative cooling of the surface less obvious at night in those area that leads to the fact that Tmin is not easy to decrease significantly.
5. Summarizing the parameters affecting DTR in the four regions of Taiwan, the average air pressure and average wind speed have almost no correlation with DTR, and the average cloud cover has no significant correlation, which may be related to atmospheric stability leading to the majority of high etage or medium etage clouds.
6. Synthesizing the results of Mingdao High School weather station, we found many main problems: insufficient of time-span, large overall data error, lack of average data, unstable observation frequency, etc., which lead to a certain degree of deviation in the results. In the future, we hope to set more uniform standards for specific meteorological parameters observation, and regularly check and update old instruments. Furthermore, it is highly possible to consider observing more DTR-related meteorological parameters.

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