

Research Article

Climate Change and Impact Analysis of Winter Wheat Overwintering Period in Changji City in Recent 30 Years

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Abstract

Changji City is located in the main producing area of winter wheat in Xinjiang. It is of great significance to study and analyze the regional climate change and its impact on the overwintering period of winter wheat for making full use of the ratio of light, heat and water resources and developing grain production according to local conditions. The data of national meteorological station and the observation data of winter wheat development period in Changji City from 1995 to 2024 were selected. The linear regression equation, climate tendency rate, Mann-Kendall and Pearson correlation coefficient method were used to analyze the variation characteristics of average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours, $\geq 0^{\circ}\text{C}$ accumulated temperature and other climatic factors during the overwintering period of winter wheat in Changji City, and to judge the key climatic factors affecting the overwintering period of winter wheat. The results showed that: (1) During the overwintering period of winter wheat in Changji City, the daily average temperature, daily maximum temperature and daily minimum temperature all showed a significant downward trend, and the downward rates were 1.3, 0.5 and $2.2^{\circ}\text{C}/10\text{a}$, respectively. The downward trend of precipitation was not significant, and the changes of sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature were not obvious; (2) There was a strong negative correlation between the number of winter wheat overwintering days and the daily average temperature, daily maximum temperature, daily minimum temperature and $\geq 0^{\circ}\text{C}$ accumulated temperature. (3) In recent 30 years, the number of winter wheat overwintering days in Changji City showed an increasing trend, which was related to the significant decrease of daily average temperature, daily maximum temperature and daily minimum temperature.

Keywords

Changji City, Winter Wheat, Overwintering Period, Climate Change, Impact

1. Introduction

Changji City of Xinjiang Uygur Autonomous Region is located in the hinterland of the Eurasian continent and the southern margin of the Junggar Basin. It belongs to the mid-temperate continental arid climate zone. It has the characteristics of cold winter, hot summer and large temperature difference between day and night [1]. Affected by the topog-

raphy, the climate varies greatly from south to north. There is more summer precipitation in the southern mountainous area, and the desert climate characteristics in the north are significant [2].

The total area of Changji City is $79.74 \times 10^4 \text{ hm}^2$, and the per capita cultivated land of farmers and herdsmen is 0.4 hm^2 .

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The landform types are generally divided into three parts: mountain, plain and desert. The terrain is high in the south and low in the north, showing a stepped shape. The middle part is an alluvial plain with high soil organic matter content, which is suitable for planting all kinds of crops. It is an important producing area of grain crops in Xinjiang.

In 2023, the planting area of grain crops in Changji City will be 16228.5 hm², of which the planting area of winter wheat will be 5252.8 hm², accounting for 31.1% of the total area of grain crops [3].

The winter wheat planting varieties in Changji City are mainly medium-strong gluten winter wheat varieties, taking into account the medium-gluten super-high-yield varieties, including Xindong 18, Xindong 22, Xindong 52, Xindong 53, etc. It is suitable to sow winter wheat with daily average temperature of 14 ~ 18°C. The accumulated temperature of $\geq 0^{\circ}\text{C}$ before winter reaches 350 ~ 650 °C, and there are 2~4 tillers at the beginning of overwintering [4]. When the average temperature in autumn is stable below 3 °C, the above-ground part of winter wheat stops growing and begins to enter the overwintering stage. According to the investigation and statistics of the agricultural department of Changji Prefecture, the overwintering period of winter wheat in Changji City is generally from the middle of November to the middle and late March of the next year.

The growth and development of winter wheat is closely related to climatic conditions. Many experts and scholars have studied and analyzed the impact of climate change on the overwintering period of winter wheat. Jing Yigang et al [5] showed that compared with the 1980 s, the starting date of winter wheat in the southern part of northern Shaanxi was delayed by about 4 days on average, and that in Guanzhong was delayed by about 8 days on average. Li Tongxiao et al [6] pointed out that the number of winter wheat overwintering days in most areas of Henan Province from 1957 to 2007 showed a shortening trend. Hu Xunyu et al [7] analyzed that the temperature increased by 0.53 °C 10a⁻¹ during the wintering-regreening period in the North China Plain from 1961 to 2008. Xie Fang et al [8] analyzed that, the climate warming trend during the growth period of winter wheat in Bachu County from 1983 to 2012 was obvious. The start of overwintering and the returning green period of winter wheat were delayed, and the whole growth period was shortened. As we all know, food security is related to national security. Changji City is located in the main winter wheat producing area along the Tianshan Mountains in northern Xinjiang. It is of great significance to study and analyze the climate change and its impact on the overwintering period of winter wheat in Changji City for making full use of the ratio of light, heat and water resources and developing food production according to local conditions.

2. Materials and Methods

2.1. Data Source

The meteorological data of the national basic meteorological station in Changji City from 1995 to 2024 and the observation data of winter wheat development period were selected. The meteorological factors included daily data such as average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours, and $\geq 0^{\circ}\text{C}$ accumulated temperature. The growth period of winter wheat was divided into seven key periods: sowing and seedling period, tillering period, overwintering period, regreening period, jointing period, heading and flowering period, and filling and maturity period [9, 10]. Because winter wheat is a cross-year overwintering crop, the harvest year of winter wheat is taken as the growth year of winter wheat, that is, from the autumn sowing of the previous year to the harvest of the next year (September of the previous year to July of the next year).

2.2. Computing Technique

The variation characteristics of climatic factors such as average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature during the overwintering period of winter wheat in Changji City were statistically analyzed by using linear regression equation and climate tendency rate method. The trend of winter wheat overwintering period was analyzed and the Mann-Kendall method was used to test the mutation [11, 12]. Pearson correlation coefficient and scatter plot method were used to analyze the correlation between winter wheat overwintering period and climatic factors in the same period, so as to determine the key climatic factors affecting winter wheat overwintering period in Changji City.

3. Results and Analysis

3.1. Variation Characteristics of Climatic Factors in Winter Wheat Overwintering Period

The regression analysis method was used to draw the change trend map of average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours, $\geq 0^{\circ}\text{C}$ accumulated temperature and other climatic factors during the overwintering period of winter wheat in Changji City from 1995 to 2024 (from mid-November of the previous year to mid-March and late March of the next year) (see Figure 1).

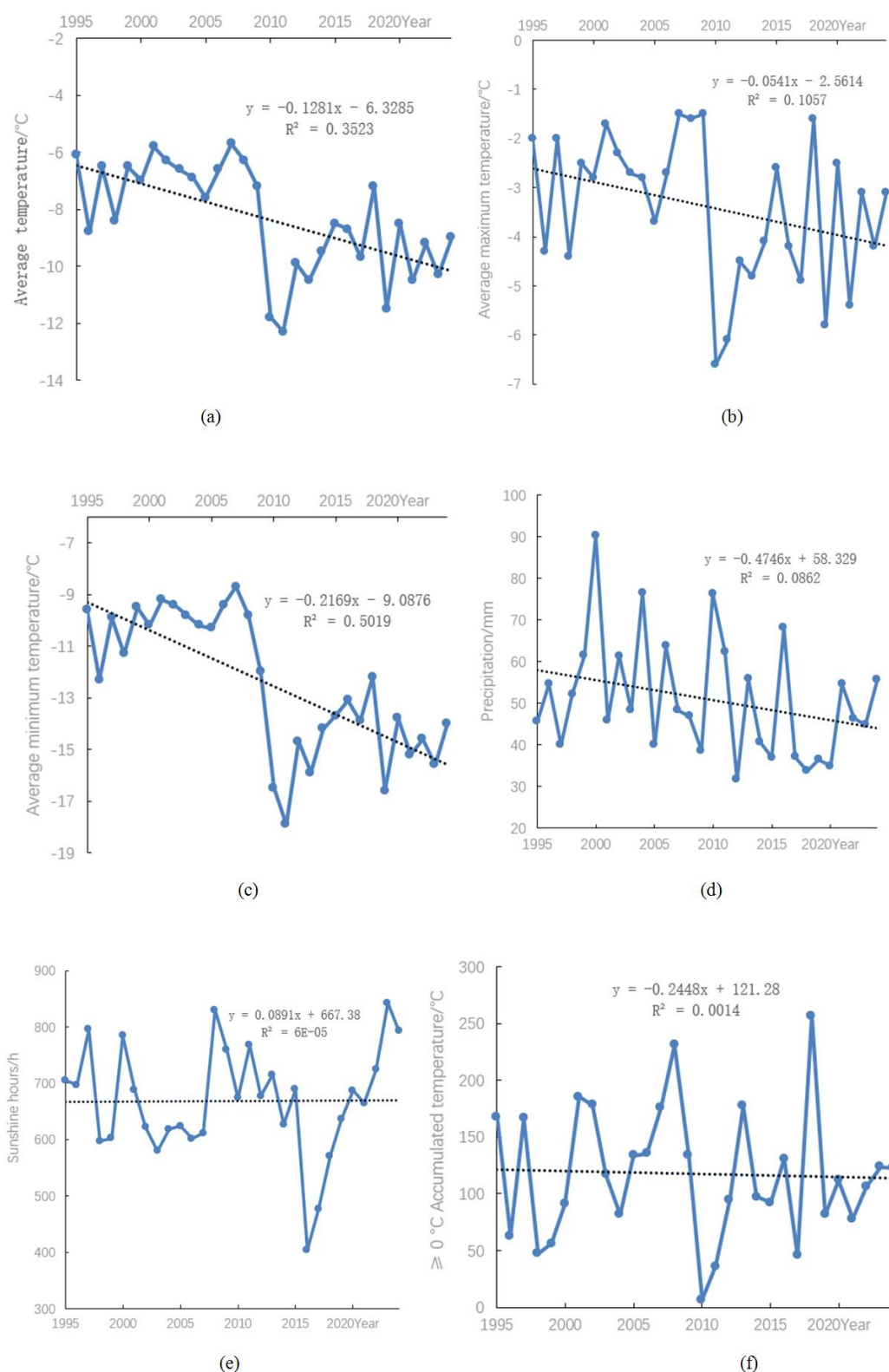


Figure 1. The Change Trend of Climatic Factors in Winter Wheat Overwintering Period in Changji City from 1995 to 2024.

(a the trend of daily average temperature change, b is the change trend of daily average maximum temperature, c is the variation trend of daily average minimum temperature, d is the change trend of precipitation, e is the change trend of sunshine hours, f is the change trend of $\geq 0^\circ\text{C}$ accumulated temperature).

According to the analysis, the daily average temperature of winter wheat in Changji City during the overwintering period

in the past 30 years showed a significant downward trend, with a trend coefficient $r = 0.5935$. Through the significance test of 0.001, the decline rate was $1.3^{\circ}\text{C} / 10 \text{ a}$. The highest value of daily average temperature appeared in 2007, which was -5.7°C , and the lowest value appeared in 2011, which was -12.3°C . The daily average maximum temperature trend coefficient $r = 0.3882$, through the 0.05 significance test, showed a downward trend, the rate of decline was $0.5^{\circ}\text{C} / 10\text{a}$. The daily average minimum temperature trend coefficient $r = 0.7084$, through the 0.001 significance test, showed a significant downward trend, the rate of decline was $2.2^{\circ}\text{C} / 10\text{a}$. The precipitation during the overwintering period showed an insignificant downward trend. The maximum value appeared in 2000, which was 90.2 mm, the minimum value appeared in 2012, which was 31.7 mm, and the maximum difference was 58.5 mm. Sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature did not pass the significance test, and the change trend was not obvious.

3.2. Trends of Winter Wheat Overwintering Period

According to the analysis, the daily average temperature of winter wheat in Changji City during the overwintering period in the past 30 years showed a significant downward trend,

with a trend coefficient $r = 0.5935$. Through the significance test of 0.001, the decline rate was $1.3^{\circ}\text{C} / 10 \text{ a}$. The highest value of daily average temperature appeared in 2007, which was -5.7°C , and the lowest value appeared in 2011, which was -12.3°C . The daily average maximum temperature trend coefficient $r = 0.3882$, through the 0.05 significance test, showed a downward trend, the rate of decline was $0.5^{\circ}\text{C} / 10\text{a}$. The daily average minimum temperature trend coefficient $r = 0.7084$, through the 0.001 significance test, showed a significant downward trend, the rate of decline was $2.2^{\circ}\text{C} / 10\text{a}$. The precipitation in the overwintering period showed an insignificant downward trend. The maximum value appeared in 2000, which was 90.2 mm. The minimum value appeared in 2012, which was 31.7 mm, and the maximum difference was 58.5 mm. Sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature did not pass the significance test, and the change trend was not obvious.

3.3. Change Trend of Winter Wheat Overwintering Days

The regression analysis method was used to draw the change trend map of the number of winter wheat overwintering days in Changji City from 1995 to 2024 (see Figure 2).

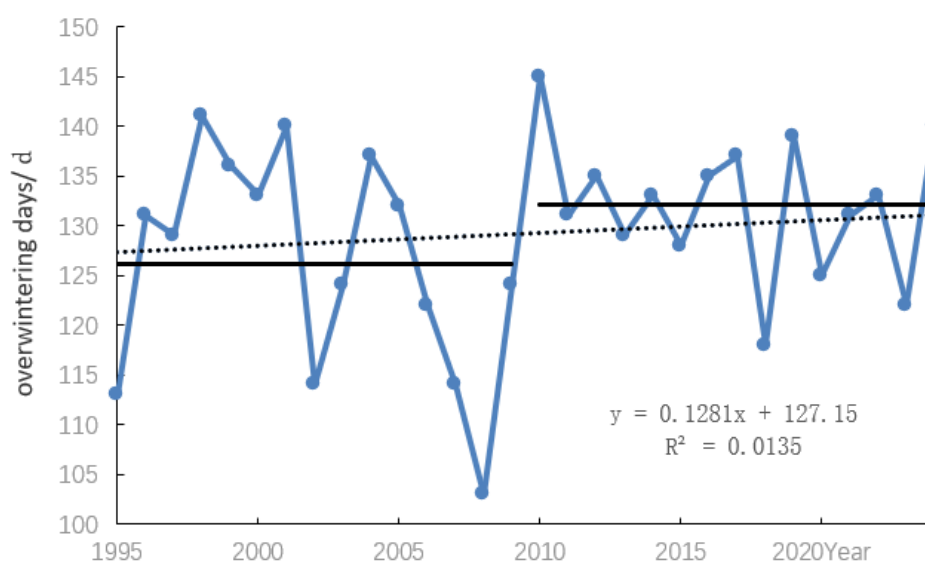


Figure 2. Variation Trend of Winter Wheat Overwintering Days in Changji City from 1995 to 2024.

The analysis showed that the number of winter wheat overwintering days in Changji City in the past 30 years showed an insignificant extension trend, and the trend coefficient did not pass the significance test. The maximum value appeared in 2010, which was 145 days, the minimum value

appeared in 2008, which was 103 days, and the maximum difference was 42 days. The average number of overwintering days before 2009 was 126 days, and the average number of overwintering days after 2010 was 132 days.

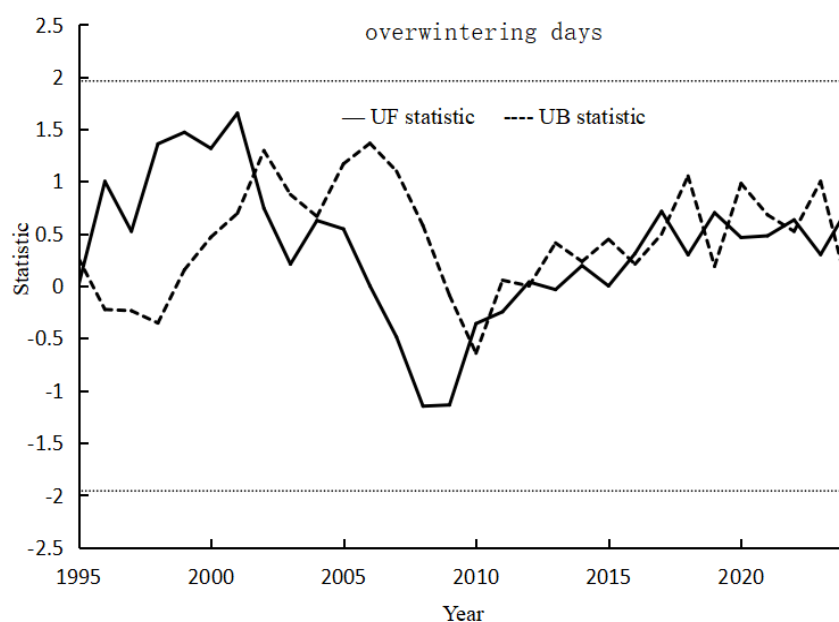


Figure 3. Mutation Test of Winter Wheat Overwintering Days in Changji City from 1995 to 2024.

The Mann-Kendall method was used to test the number of winter wheat overwintering days in Changji City from 1995 to 2024 (see Figure 3). The results showed that there was no obvious mutation in the overwintering period of winter wheat in Changji City in the past 30 years.

3.4. Trend of the Start Date of Winter Wheat Overwintering

Affected by the weather conditions in the early period of

overwintering, the start date of winter wheat overwintering is different every year. According to statistics, the start date of winter wheat overwintering in Changji City over the years is November 14. By comparing the number of days in advance or postponed between the start date of winter wheat overwintering in Changji City from 1995 to 2024 and the start date of winter wheat overwintering over the years, the change trend of the start date of winter wheat overwintering in Changji City can be obtained (see Figure 4).

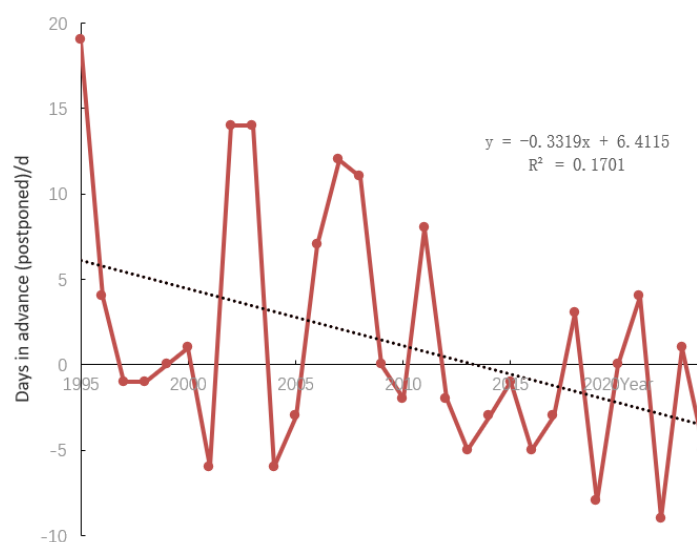


Figure 4. Variation Trend of Winter Wheat Overwintering Start Period in Changji City from 1995 to 2024.

The analysis showed that the start date of winter wheat overwintering in Changji City in the past 30 years showed a

significant advance trend, and the trend coefficient $r = 0.4124$. Through the significance test of 0.05, the advance rate was 3.3

d / 10 a, and the trend was more obvious after 2010.

3.5. Correlation Analysis of Winter Wheat Overwintering Period

Using scatter plot and Pearson correlation coefficient method, the correlation analysis of winter wheat overwintering days and climatic factors such as average temperature, maximum temperature, minimum temperature, precipitation, sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature in Changji City from 1995 to 2024 was carried out, and Table 1 was obtained.

Table 1. The Correlation and Coefficient Between Winter Wheat Overwintering Days and Climatic Factors in Changji City.

Climatic factor	Correlation equation	Correlation coefficient
Daily average temperature	$y=-2.5092x+108.27$	0.4913**
Daily average maximum temperature	$y=-3.8480x+116.05$	0.5813**
Daily average minimum temperature	$y=-1.4606x+110.95$	0.4060*
Precipitation	$y=0.1529x+121.34$	0.2243
Sunshine hours	$y=-0.0208x+143.05$	0.2105
$\geq 0^{\circ}\text{C}$ accumulated temperature	$y=-0.1181x+143.01$	0.7001**

Annotation: *, ** represent the significance level test of 0.05 and 0.001 respectively.

It can be seen from the above table that the correlation coefficient between the number of winter wheat overwintering days and climatic factors in Changji City is between 0.2105 and 0.7001. The correlation coefficients of the daily average temperature, the daily average maximum temperature and $\geq 0^{\circ}\text{C}$ accumulated temperature all pass the significance test of $\alpha = 0.001$, and the correlation coefficient of the daily average minimum temperature passes the significance test of $\alpha = 0.05$, indicating that there is a strong negative correlation between the number of winter wheat overwintering days and the daily

average temperature, daily average maximum temperature, daily average minimum temperature and $\geq 0^{\circ}\text{C}$ accumulated temperature during the overwintering period in Changji City. When the above climatic factors show a downward trend, the number of winter wheat overwintering days will show an extended trend.

4. Conclusion and Discussion

From 1995 to 2024, the daily average temperature, daily average maximum temperature and daily average minimum temperature of winter wheat in Changji City showed a significant downward trend during the overwintering period, and the decline rates were 1.3, 0.5 and $2.2^{\circ}\text{C} / 10 \text{ a}$, respectively. The precipitation during the overwintering period showed no significant downward trend, and the sunshine hours and $\geq 0^{\circ}\text{C}$ accumulated temperature did not change significantly.

In the past 30 years, the number of winter wheat overwintering days in Changji City showed an insignificant extension trend. The maximum value appeared in 2010, which was 145 days, and the minimum value appeared in 2008, which was 103 days. The beginning of overwintering of winter wheat showed a significant advance trend, and the advance rate was $3.3 \text{ d} / 10 \text{ a}$.

There is a strong negative correlation between the number of winter wheat overwintering days in Changji City and the daily average temperature, daily average maximum temperature, daily average minimum temperature and $\geq 0^{\circ}\text{C}$ accumulated temperature during the overwintering period. When the above climatic factors show a downward trend, the number of winter wheat overwintering days will show an extended trend, which is consistent with the research results of Abuduk Rim Abbasi et al [13].

In the past 30 years, the number of winter wheat overwintering days in Changji City showed an extended trend, which was related to the significant decrease of daily average temperature, daily average maximum temperature and daily average minimum temperature. The winter wheat forms strong seedlings before winter, and the light, temperature and water configuration are suitable in the three ecological stages of freezing and thawing, stable freezing and thawing, which is conducive to the safe overwintering of winter wheat [14-16]. Therefore, it is necessary to strengthen the management of winter wheat production technology before and after winter in Changji City to ensure stable and high yield of winter wheat.

Abbreviations

Mann-Kendall method	It Is a Non-parametric Test Method Recommended by the World Meteorological Organization and Widely Used in Practical Research. It Is One of the Time Series Trend Analysis Methods.
Pearson correlation coefficient	It Is to Measure Whether Two Data Sets Are on A Line, Which Is Used to Measure the Linear Relationship Between Fixed Distance Variables.

Author Contributions

Jian Yong-mei is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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Biography

Jian Yong-mei (1976—), female, Han nationality, Master's Degree, Senior Engineer, The main research directions are resources and environment, meteorological services and applied meteorology.