Maximum and Minimum Temperature in Naiman County, China

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Abstract. The trends of mean temperature, maximum temperature (Tmax) and minimum temperature (Tmin) data from Naiman National automatic meteorological station were analyzed on annual, seasonal and monthly scales over the 1970-2013 periods. Results indicated: (1) The average annual mean temperature, Tmax and Tmin in Naiman County was 7.1℃, 13.5℃ and 1.6℃, respectively, and average annual mean temperature, Tmax and Tmin all increased, at a rate of of 0.29℃/10a, 0.24℃/10a and 0.28℃/10a, respectively, which were all higher than global nearly 50 years (0.13℃/10a); (2) The average annual mean temperature of spring, summer, autumn and winter was 8.3℃, 22.6℃, 7.7℃ and -10.1℃, respectively; The increasing speed of mean temperature, Tmax and Tmin were all most obviously at spring, at a rate of 0.38℃/10a, 0.3℃/10a and 0.38℃/10a, respectively; (3) The highest and lowest mean temperature was obtained at July (23.9℃) and January (-10.1℃), respectively; The highest and lowest Tmax was obtained at July (23.9℃) and January (-5.9℃), and the highest and lowest Tmin was obtained at July (19.1℃) and Dec. (-14.3℃).

1. Introduction
Air temperature as one of the most important variables in climate research and global change, controls many biological and physical processes between the hydrosphere, atmosphere and biosphere[1]-[2]. The analysis of long-term trends of air temperature is essential for the assessment of the impacts of climate variability and change in a given area[3]. The interest in assessing climate changes using air temperature resides not only in mean temperature, but also maximum and minimum temperatures (Tmax and Tmin), because changes in mean temperature are caused by changes in either Tmin or Tmax, or both[4]-[6].

Naiman County is located in the eastern part of Inner Mongolia, China. This area has become one of the most severely affected by desertification in northern China due to long-term overgrazing, reclamation, gathering of fire wood, and excessive utilization of water resources[7], and are generally thought to originate from sand and dust storms that occur frequently in the arid and semi-arid regions of northern China[8]-[9].

The main objective of this study was to provide a brief trend of mean temperature, Tmax and Tmin at the scales of monthly, seasonal and annual in Naiman County, and original data collected from Naiman National automatic meteorological station with continuous record over the period 1970-2013.

2. Materials and Methods
2.1. Study Area Description
The study was conducted in the eastern part (42°55’N, 120°42’E; 360 m elevation) of Inner Mongolia, China (Figure 1). The climate is temperate, semi-arid, continental, and monsoonal. The area receives
357 mm of precipitation annually. Mean annual potential pan-evaporation is approximately 1935 mm. The mean annual temperature is 6.8°C. The annual frost-free period is 130–150 days. The average annual wind speed is 3.4 m s⁻¹[9]. Soils are sandy, light yellow, have loose structure, and are particularly susceptible to wind erosion[7]. Moving dunes are the most typical feature in this area; depth to groundwater is between 12 and 15 m, therefore, groundwater is unable to supply surface soil water.

![Figure 1. Locations of study area](image)

2.2. Data
All data used hereby were extracted from the Naiman National automatic meteorological station. This station with continuous data record was involved in the analysis. The analysis was applied on the mean temperature (°C); mean maximum temperature (Tmax) (°C); mean minimum temperature (Tmin) (°C), for the 1970-2013 intervals.

2.3. Methods
Temperature (°C) changed with year was regressed by the linear equation: \( Y = at + b \), where: \( t \) is the year; \( A = a \cdot 10 \) was the trend rate of temperature. The value of \( A \) can describe the variation of temperature series, and a positive (negative) \( A \) represents linear increasing (decreasing) of the temperature in the statistical time[10]. Trends of significance test chose F-test method. The trend analysis and F-test were completed by Origin8.0 software.

3. Results and Discussion

3.1. Annual Temperature
The average annual mean temperature, Tmax and Tmin in Naiman County was 7.1°C, 13.5°C and 1.6°C, respectively (Table 1). The coefficient of variation of annual temperature was smallest for Tmax (CV=0.06), next was mean temperature (CV=0.1), and the coefficient of variation of Tmin was bigger (CV=0.4).

| Month | Mean temperature | Tmax | Tmin |
|-------|------------------|------|------|
|       | Mean | SD  | CV  | Mean | SD  | CV  | Mean | SD  | CV  |
| Jan.  | -12.32 | 2.17 | -0.18 | -5.90 | 2.34 | -0.40 | -17.13 | 2.13 | -0.12 |
| Feb.  | -8.37  | 2.40 | -0.29 | -1.55 | 2.75 | -1.78 | -13.82 | 2.27 | -0.16 |
| Mar.  | -9.91  | 2.07 | -2.28 | 5.80  | 2.17 | 0.37  | -6.72  | 2.13 | -0.32 |
| Apr.  | 9.07   | 1.89 | 0.21  | 15.83 | 2.36 | 0.15  | 2.70   | 1.48 | 0.55  |
The linear trends of average annual mean temperature, Tmax and Tmin along with year (between 1970 and 2013) (Figure 2) showed that they were all increased. The linear regression equation of average annual mean temperature, Tmax and Tmin (Table 2) showed that the intercept of line was between 0.024~0.029, the $R^2$ were all larger than 0.15. The variability of mean temperature was 0.29℃/10a, the variability of annual Tmax and Tmin was 0.24℃/10a and 0.28℃/10a, respectively, which were all higher than global nearly 50 years (0.13℃/10a)[11]. The highest and lowest mean temperatures occurred at 2007 (8.6℃) and 1974 (5.7℃), respectively.

![Figure 2](image)

**Figure 2.** Linear trends of annual mean temperature, Tmax and Tmin with year.

**Table 2.** Linear regression equation of mean temperature, Tmax and Tmin of annual, spring, summer, autumn and winter.

| Time  | Temperature | Linear equation | $R^2$ | Time  | Temperature | Linear equation | $R^2$ |
|-------|-------------|-----------------|-------|-------|-------------|-----------------|-------|
| Mean  | y = 0.038x + 7.419 | 0.168          | Mean  | y = 0.026x + 22.010 | 0.171          |
| Spring| Tmax        | y = 0.030x + 14.291 | 0.088 | Summer| Tmax        | y = 0.024x + 27.813 | 0.094 |
|       | Tmin        | y = 0.038x + 1.183 | 0.190 |       | Tmin        | y = 0.022x + 16.875 | 0.176 |
|       | Mean        | y = 0.025x + 7.081 | 0.116 |       | Mean        | y = 0.021x - 10.593 | 0.028 |
| Autumn| Tmax        | y = 0.027x + 13.623 | 0.085 | Winter| Tmax        | y = 0.015x - 4.048 | 0.011 |
|       | Tmin        | y = 0.019x + 1.703 | 0.078 |       | Tmin        | y = 0.027x - 15.641 | 0.051 |
| Annual| Mean        | y = 0.029x + 6.453 | 0.269 |       |             |                 |       |
The increasing trend of temperature (mean temperature, Tmax and Tmin) in Naiman County was consistent with the trend in global temperatures. In addition, Tmin was increased faster than Tmax, this was consistent to the related results, e.g., Hua et al.[6] indicated that the average annual mean Tmax and Tmin over China increased by 0.147°C/10a and 0.283°C/10a respectively; Hughes showed that Australia has warmed ~0.8°C over the last century with Tmin warming faster than Tmax[12]; Uddin et al. showed that there is an increasing trend in the annual mean Tmax and Tmin in Bangladesh region between 1948 and 2013, and the annual mean Tmax increased by 0.0037°C per year, while the annual mean Tmin experienced a 0.069°C increased between 1948 and 2013[13]. The related research results also showed that there was obvious warming over the past century for many parts of the world[6],[14]-[15], and the distributions of both daily Tmax and Tmin have significantly shifted towards higher values[16]. In most regions, both Tmax and Tmin have become more positively skewed in more recent decades which indicates a change in shape towards the hotter part of the distribution [16].
The trend rate and significance test of linear regression equation of mean temperature, Tmax and Tmin showed (Table 3) that the trend rate (A) of annual temperature (mean, Tmax and Tmin) were 0.24–0.29, and they all increased insignificant (F>7).

### Table 3. Temperature trend and its significance test of linear regression equation of mean temperature, Tmax and Tmin at annual, spring, summer, autumn and winter.

| Time | Spring | Summer | Autumn | Winter | Annual |
|------|--------|--------|--------|--------|--------|
| **Parameters** | A   | F    | A    | F    | A     | F    | A    | F    | A     | F    |
| Mean  | 0.38  | 8.47  | 0.26  | 8.63  | 0.25  | 5.50 | 0.21  | 1.17  | 0.29  | 15.46 |
| Tmax  | 0.30  | 4.03  | 0.24  | 4.37  | 0.27  | 3.92 | 0.15* | 0.45  | 0.24  | 7.66  |
| Tmin  | 0.38  | 9.84  | 0.22  | 8.99  | 0.19  | 3.53 | 0.27  | 2.21  | 0.28  | 16.04 |

*p<0.5.

### 3.2. Seasonal Temperature

The division of the season in the study area as following: spring was Mar. to May, summer was Jun. to Aug., autumn was Sept. to Nov., and winter was Dec. to Feb. of next year[10].

The statistical characteristics of mean temperature, Tmax and Tmin at four seasons were also listed in Table 1. It indicated that the mean temperature of spring, summer, autumn and winter was 8.3°C, 22.6°C, 7.7°C and -10.1°C, In addition, the mean temperature and Tmax changed with season in the order: summer > spring > autumn > winter, but for Tmin, it was higher at autumn than spring. The highest coefficient of variation of mean temperature, Tmax and Tmin was autumn, winter and spring, respectively, and the coefficient of variation of three temperatures (mean, Tmax and Tmin) were all lowest at summer. That was, the temperature of summer was relatively stable in different years.

The linear trends of mean temperature, Tmax and Tmin at four seasons indicated that (Figure 3) they all increased with year. The linear regression equation, the trend rate and significance test of mean temperature, Tmax and Tmin at spring, summer, autumn and winter were also listed in Table 2 and Table 3, respectively.

The increasing trend of mean temperature was most obviously at spring (0.38°C/10a), and weakest at winter (0.21°C/10a). The highest and lowest mean temperatures of spring were 11.1°C of 2002 and 6.1°C of 2010; The highest and lowest mean temperature of winter were -6.9°C of 2006 and -13.1°C of 2012. The increasing trend of Tmax was also most obviously at spring (0.3°C/10a), and weakest at winter (0.15°C/10a), but the increasing trend of Tmin was most obviously at spring (0.38°C/10a), and weakest at autumn (0.19°C/10a). In four seasons, for mean temperature, Tmax and Tmin, only Tmax of winter increased significant (F<0.5) (Table 3).
Figure 3. Linear trends of seasonal mean temperature, Tmax and Tmin with year.

3.3. Monthly Temperature
The statistical characteristics of mean temperature, Tmax and Tmin in different months were also showed in Table 1. The highest and lowest mean temperature was obtained at July (23.9°C) and January (-12.3°C), respectively. In addition, the mean temperature and Tmax of different months were decreased in the order: Jul. >Aug. >Jun. >May. >Sept. >Apr. >Oct. >Mar. >Nov. > Feb. >Dec. >Jan. However, the order of Tmin in different months was different to mean temperature and Tmax, e.g., Tmin at Sept. was higher than May, and Nov. was higher than Mar. The highest and lowest Tmin was obtained at Jul. (19.1°C) and Dec. (-14.3°C). The coefficient of variation of mean temperature, Tmax and Tmin were highest at March, Feb and Apr. And it was lower for mean temperature, Tmax and Tmin from May to Sept. The bigger coefficient of variation of temperature (mean, Tmax and Tmin) occurred between Feb. to Apr. mainly because frequent winds between November to May makes this period the major wind-erosion season, especially between Feb. to Apr.[8].

4. Conclusions
We presented a trend analysis in mean temperature, Tmax and Tmin at scales of annual, seasonal and monthly over 1970-2013. The main conclusions are as follows.
(1) The annual mean temperature, Tmax and Tmin in Naiman County was 7.1°C, 13.5°C and 1.6°C, respectively. There is a general warming signal for mean temperature, Tmax and Tmin over Naiman County, with increasing speed of 0.29°C/10a, 0.24°C/10a and 0.28°C/10a, respectively;
(2) The mean temperature of spring, summer, autumn and winter was 8.3°C, 22.6°C, 7.7°C and -10.1°C; The increasing degree of mean temperature, Tmax and Tmin were all most obviously at spring, with increasing speed 0.38°C/10a, 0.3°C/10a and 0.38°C/10a, respectively;
(3) The highest and lowest mean temperature was obtained at July (23.9°C) and January (-12.3°C), respectively; The highest and lowest Tmax was obtained at July (23.9°C) and January (-5.9°C), respectively;
respectively; The highest and lowest Tmin was obtained at July (19.1°C) and Dec. (-14.3°C), respectively.

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