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# Long-term trends in daily temperature extremes over Mongolia

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ABSTRACT

Various indices have been used to investigate recent changes in the annual frequencies of extreme temperature events in Mongolia. A high-quality daily temperature dataset including 53 station records was used to determine trends from 1961 to 2010. The Climdex1.0 software was used to calculate 11 extreme temperature indices for this study. The results showed significant changes in important temperature indices over the study period, especially in the Gobi Mongolia. The analysis showed that an apparent increase in summer days was observed, while an appreciable decrease in frost days was observed. The maximum values of daily maximum temperature (TXx) and daily minimum temperature (TNx) and the minimum values of $T_{max}$ (TXn) and $T_{min}$ (TNn) tended to increase. However, for TXx and TNx, this increasing trend was mainly observed in the Gobi Mongolia, while for TXn and TNn, this increasing trend was observed over the entire country. A significant reduction at a rate of $-0.6$ d decade$^{-1}$ ($-1.0$ d decade$^{-1}$) occurred for cool nights (days), and a significant increase at a rate of 2.8 d decade$^{-1}$ (3.1 d decade$^{-1}$) occurred for warm nights (days). The reduction of cool nights and cool days occurred over four seasons, while the increase of warm days and warm nights occurred mainly in summer.



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## 1. Introduction

It is widely known that enhanced atmospheric greenhouse gases contributed to an increase in global mean surface temperature (IPCC, 2007; Alexander et al., 2007). Human activities and the environment are greatly affected by extreme climatic events, such as heat waves, floods and droughts (Moberg and Jones, 2005).

Variations of mean and extreme values of climatic variables as well as the shape of their statistical distribution can be used to characterize climate change. Even though knowledge of climate extremes is required to develop and manage emergency situations, the study of climate change using climate extremes is rather complex. A set of suitable indices describing the extremes of the climate variables can be used for the study of climate change. Mongolia has a highly continental climate with long, dry and very

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cold winters and hot summers. Consequently, four seasons in Mongolia are very distinctive and months within each of them are quite distinctive (Nandintsetseg et al., 2007). It is widely known that Mongolia has the landlocked geography, dispersed and sparse population and harsh temperate climate and due to these conditions Mongolia is very vulnerable to immensely changing weather conditions.

Today, unlike other developing countries, Mongolia has specific concerns related to unique geographical and climatic conditions of Mongolia. Economy and ecosystems in Mongolia are greatly affected by the risk of climate change and/or extreme climatic events such as drought and *dzud* (a Mongolian term for a severe winter). Weather stations data from 1961 to 2001 have been used for climate extreme indices change study since 2003 (Dagvadorj et al., 2009).

A suite of indices through the coordination of the Expert Team on Climate Change Detection, Monitoring and Indices (ETCCDMI) working under the joint WMO Commission for Climatology (CCl)/ World Climate Research Programme (WCRP) Climate Variability and Predictability (CLIVAR) project (Peterson et al., 2001) have been developed, calculated, and analyzed to rationalize and standardize the expressions for extreme weather events.

The purpose of this study was to investigate changes in temperature extreme events through the long-term trend in the frequency of extreme temperature events in Mongolia using 11 extreme temperature indices.

## 2. Data and methodology

### 2.1. Data and quality control

Mongolia is located in the Northern Hemisphere (approximately, 43–52°N and 85–120°N) at an average altitude of 1500 m, surrounded by high mountain ranges that are blocking the wet winds.

The National Agency for Meteorology and Environmental Monitoring (NAMEM) of Mongolia, a governmental agency, operates the meteorological observation network of Mongolia. The Persona-win software has been used for the data quality control. Before the climate data from the meteorological observation network of Mongolia are archived by NAMEN, these data are collected and quality controlled (Namkhajantsan et al., 2006).

Currently, 130 meteorological stations were operated by NAMEM (Battur, 2010). Fifty three meteorological stations, where daily maximum and minimum surface air temperature data between 1961 and 2010 are available from, were selected for this study. These collected data were also quality controlled by a data quality control procedure in the RClimDex package before the extreme indices were calculated by the RClimDex package (Zhang and Yang, 2004). This data quality control procedure is substantially given by Zhang and Yang (2004). It should be noted that an observation was considered as an outlier if it is more than four standard deviations from the mean.

Mongolia is geographically divided into four regions: Western Mongolian (WM, high mountain region), Central Mongolian (CM, forest region), Eastern Mongolian (EM, steppe region), and Southern Mongolian (SM, Gobi desert region). The locations of 53 meteorological stations are depicted in Fig. 1.

A regression based homogeneity test of the RHtestsV3 software (Wang and Feng, 2010) was used to detect significant artificial shifts. Quality control of daily temperature was conducted and its homogeneity was also tested before the calculation of temperature extreme indices. These indices were computed for each season (standard seasons) and year and for each station where less than 2% of data were missing. The trends of the seasonal time series of all indices have been analyzed for each station. The magnitude of seasonal trends was estimated using the linear regression method, while its statistical significance was evaluated using the Kendall–Tau test. The method of Kendall's $\tau$ statistics was proposed by Dietz and Killeen (1981). A monotone trend based on Kendall's $\tau$ was further extended to statistical analysis of seasonal variability (Hirsch et al., 1982). Kendall's statistic $S$ is computed as follows:

$$S=\sum_{i=1}^{n-1}\sum_{k=i+1}^{n}\operatorname{sgn}(x_k-x_i)$$

$$\operatorname{var}(S)=\frac{n(n-1)(2n+5)-\sum_{i=1}^{m}e_i(e_i-1)(2e_i+5)}{18} \tag{1}$$

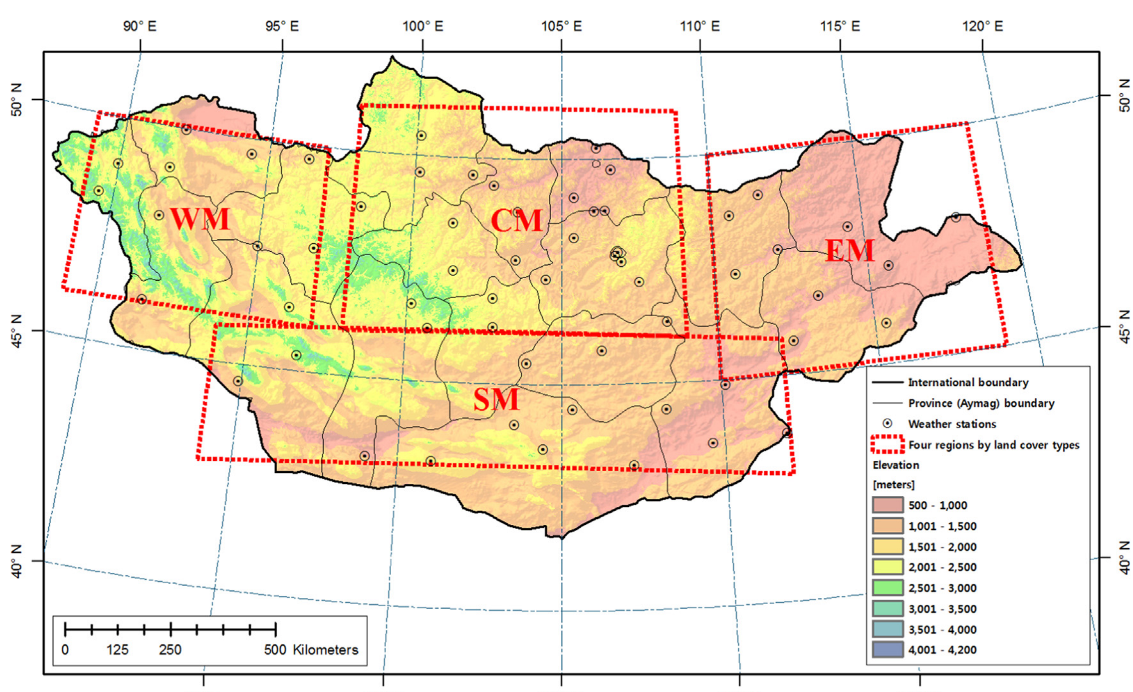


**Fig. 1.** Map of Mongolia with the locations of the stations.