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Analysis of diurnal air temperature range change in the continental United States

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ABSTRACT

Diurnal temperature range (DTR) is an important indicator for climate change. In this paper, diurnal air temperature range variations of the continental United States over the past one hundred years were investigated to discover the temporal trend and spatial patterns. While the annual mean DTR of the United States has steadily decreased during the past decades, it is found that the decreased amplitude has spatial and seasonal patterns. Seasonal and spatial variations of DTR were analyzed for the four regions, northeastern, northwestern, southeastern, and southwestern. Fall and summer witnessed a significant decrease in DTR in all regions. Spring and winter, on the other hand, have experienced much smaller decreases. Temporal trend and spatial patterns of daily maximum and minimum temperatures were also investigated to gain insight of DTR change.

1. Introduction

Daily mean temperature is generally used as a universal measurement for climate change study. However, mean temperature alone is not enough to reflect the complicated variations of climate. In fact, trends in mean surface temperature are often due to changes in daily maximum and minimum temperatures (Sun et al., 2006). So, diurnal temperature range is also an important indicator for climate change (Karl et al., 2004). DTR has steadily decreased throughout the United States (Karl et al., 1991), which can be attributed to the increase in mean daily temperature and a steady daily maximum temperature (Karl et al., 1991; Karl et al., 1984). Karl et al. studied cloudy and clear sky conditions and their impacts on diurnal temperature range (Karl et al., 1987). They found a significant decrease in diurnal temperature range over time during cloudy days. Many other additional factors that affect in diurnal temperature range including land use/land cover changes (Gallo et al., 1996), irrigation (Karl et al., 1988), station moves, desertification, and other climatic effects (Karl et al., 1993). Urbanization, also, has been extensively investigated in many papers (Karl et al., 1988; Landsberg, 1981; Wang et al., 2012). It was found that as the population of an urban center increases, the diurnal temperature range would shift in an asymmetrical manner (Karl et al., 1991). Despite these confounding variables, many studies have been conducted on diurnal temperature range study. A variety of data and methods have been used. Most studies utilized station observations and analyzed the trends of diurnal temperature range on global level (Karl et al., 2004; Easterling et al., 1997; Leathers et al., 1998). Karl et al. studied the decreasing diurnal temperature range in the United States and Canada (Karl et al., 1991). Sun et al. used satellites measurements to evaluate the diurnal temperature range (Sun et al., 2006). Park and Joh used climate models to predict diurnal temperature range changes (Park and Joh, 2005). These studies have analyzed the diurnal temperature range in the United States, but many of these studies used limited number of station observations, or covered limited historical period.

The primary objective of this study is to analyze the diurnal temperature range changes over the continental United States since 1911 through spatial and temporal analysis of observations from thousands of stations over the continental United States. The United States was separated into 4 regions where the trends of each region were analyzed as well as the United States as a whole. The four regions were analyzed through their four seasons as well as their yearly averages. DTR, as well as daily maximum temperature (TMAX) and minimum temperature (TMIN) are not only analyzed for region to region differences, but also, season to season differences.

2. Data and methodology

2.1. Data and study area

For this study, daily maximum and minimum air temperature was obtained from the National Climate Data Center's Global

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Historical Climatology Network Daily (Menne et al., 2012). The Global Historical Climatology Network Daily contains records from over 75,000 stations around the world. Maximum and minimum air temperature, snowfall, snow depth, and daily precipitation are primary variables provided by these stations (Menne et al., 2012). The data is comprised of daily climate records from numerous sources that have been integrated to a plethora of quality assurance reviews (Menne et al., 2012). The Global Historical Climatology Network Daily contains the most complete collection of United States daily climate summaries available, even provides some of the earliest observations available for the United States.

In this study, we focused on DTR analysis over the continental United States from year 1911–2012. Time series of daily maximum temperature and minimum temperature were also analyzed for further understanding of DTR trend. We investigated DTR change of the continental United States first, then analyzed spatial variations of DTR trends by separating into four spatial regions with longitude and latitude. The northern and southern regions were separated at 40° latitude, and the eastern and western portions were separated at the −100° longitude. We can mark these four regions as North West Region (NWR), North East Region (NER), South West Region (SWR), and South East Region (SER).

2.2. Method

Daily DTR data was obtained by subtracting daily minimum temperature from daily maximum temperature at each station. Then, spatial and temporal averages were conducted for regional, annual and seasonal analysis to get DTR time series for the continental United States and the four study regions.

Regional mean DTR, regional mean maximum temperature and regional mean minimum temperature are the average of DTR, daily maximum temperature and daily minimum temperature, respectively, at stations within the specified spatial area, i.e.

$$DTR_{region} = \frac{1}{N}\sum_j DTR_j.$$

$$TMAX_{region} = \frac{1}{N}\sum_j TMAX_j$$

$$TMIN_{region} = \frac{1}{N}\sum_j TMIN_j$$

where N is the number of stations over the specified region, DTR_j, $TMAX_j$ and $TMIN_j$ are daily DTR, maximum temperature and minimum temperature for the No. j station of the study region, respectively. Monthly DTR was calculated by averaging DTR for each month. Annual mean DTR was obtained through yearly average of regional DTR. And similarly, seasonal mean DTR was obtained by averaging DTR over specified season. Monthly and seasonal average maximum and minimum temperatures were obtained similarly.

Since the duration of each season changes with geolocation, in this study, we used the approximate season period for northern hemisphere, i.e. Feb. Mar. and Apr. for spring, May, Jun. and Jul. for Summer, Aug., Sep., and Oct. for fall, and Nov., Dec. and Jan. for winter.

3. Results and analysis

3.1. DTR trend of the continental USA

Fig. 1 illustrates the yearly average diurnal air temperature range, maximum air temperature, and minimum air temperature of the continental USA from year 1911–2012. Despite the fluctuations from year to year because of various climate factors, a steadily decreasing trend of DTR can be identified statistically, with a slope of −0.004658 °C/yr. Especially, during recent decades, the decreasing trend is more significant. Since 1991, the yearly mean DTR are usually below 13.5 °C. As demonstrated in Fig. 1, the annual mean maximum air temperature has a slightly increasing

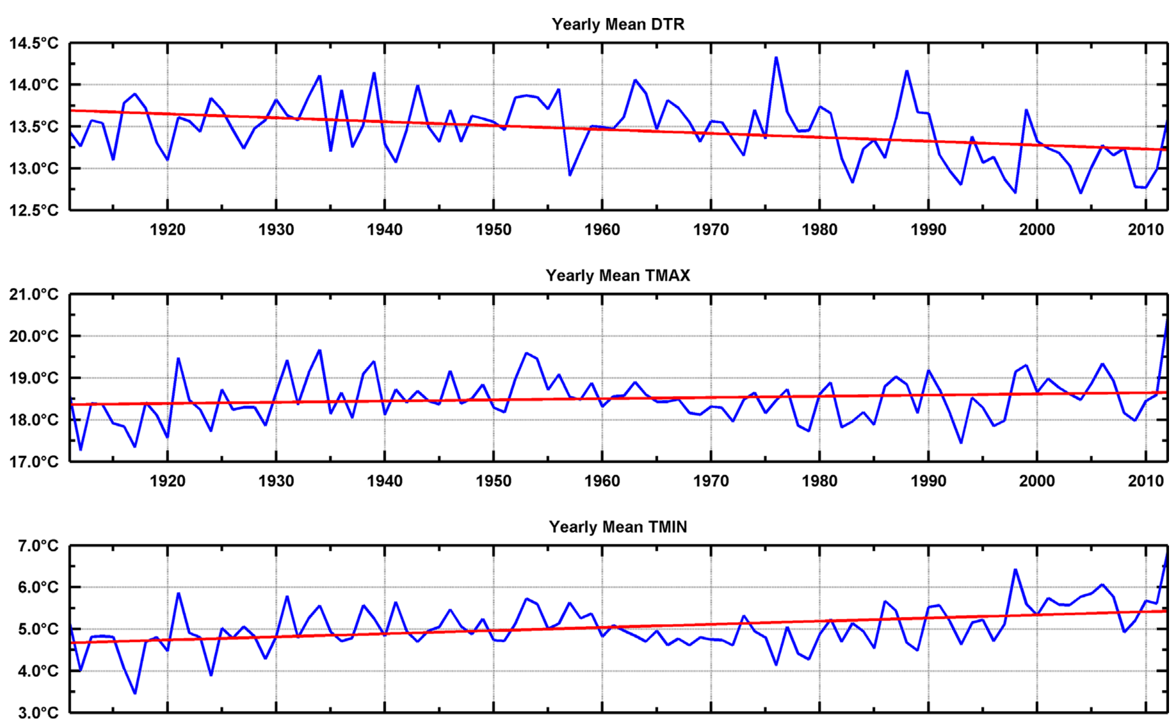

Fig. 1. Yearly average diurnal air temperature range (DTR), maximum air temperature, and minimum temperature of the continental USA.