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ORIGINAL PAPER

Temperature trend–altitude relationship in China during 1963–2012

Danhong Dong · Gang Huang · Xia Qu · Weichen Tao · Guangzhou Fan

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Abstract Based on daily air temperature data from 745 stations in China, the present study investigates the regional characteristics of temperature trend and the dependence of temperature changes on the altitude during the period of 1963–2012. There is a consistent warming trend throughout the country except for the southwest China where a cooling trend is identified. Moreover, significant warming trend exists in highland areas such as the Northeast, Inner Mongol, and the Tibet region. Compared with other seasons, the warming trend is most pronounced in highland regions in winter. In summer, the temperature has no obvious increasing trend in north China, while the cooling trend is found in south China. The relationship between altitude and temperature trend is further investigated by dividing China into three subregions according to the altitude—below 200, 200–2,000, and above 2,000 m. Although there is no simple linear relationship between elevation and warming trend on national scale, the temperature trend–altitude relation is different among the three regions. The temperature trend decreases with altitude below 200 m while increases from 200 to 2,000 m, and a weak positive temperature trend–altitude relation is found over 2,000 m. The strongest temperature trend–altitude relations are found in the subtropical regions, especially pronounced south of 36°N in China. The magnitudes of decreases from 200 to 2,000 m are one order lower than the increases below 200 m. Low-altitude stations appear to be influenced more by anthropogenic aerosols. High-altitude stations are mostly located in flat terrain and sparsely populated region. Therefore, temperature trends change with elevations.

D. Dong
State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics (LASG), Beijing 100029, China

D. Dong · G. Fan
Plateau Atmosphere and Environment Key Laboratory of Sichuan Province, Chengdu University of Information Technology, Chengdu, China

G. Huang (✉) · W. Tao
Key Laboratory of Regional Climate-Environment for East Asia, Chinese Academy of Sciences, Institute of Atmospheric Physics, Beijing, China 100029
e-mail: hg@mail.iap.ac.cn

G. Huang
Collaborative Innovation Center on Forecast and Evaluation of Meteorological Disasters, Nanjing, China

X. Qu
Center for Monsoon System Research, Chinese Academy of Sciences, Institute of Atmospheric Physics, Beijing, China

1 Introduction

The Fifth Assessment Report of Intergovernmental Panel on Climate Change indicated that human activity is the dominant cause of observed warming since the mid-twentieth century. The last three decades have been successively warmer at the Earth's surface than any preceding decades since 1850 (Stocker et al. 2013). Since 1950s, the recurring time of the southwest mountain hazard has been shortened, corresponding to the frequent occurrences of meteorological disasters and loss in the southwest. Besides, with the potential increasing trend of desertification in the semi-arid lands, the mountain meadow boundary may rise from 380 to 600 m. In addition, the distribution pattern of the Permafrost Regions of the Tibetan Plateau has changed tremendously (Ding et al. 2006).

Plateaus and mountains cover about 25 % of continental areas (Price and Butt 2000), and they are sources of many major river systems, being a key element of the hydrological cycle (Beniston et al. 1997). Particularly, China has a complex topography and mountainous areas accounting for two-thirds of nation territory. Meanwhile, regional climate is influenced by a combination of factors, such as continent position, latitude, longitude, associated atmospheric circulation systems, and topography. Those lead to an uneven response to global changes in different ways (Lu et al. 2006). The large mountain areas in China with huge latitude span are influenced by multiple circulation systems and especially sensitive to climate change. Thus, the analysis of temperature change with altitude in China not only deepens the understanding of global warming, but also contributes to the study of hydrologic cycle, ecological environment, and climate change regionally and globally.

In terms of mountain areas, the Tibetan Plateau, as a sensitive region to global climate, exerts huge influences on atmosphere and hydrological cycle. Previous studies revealed that there is an obvious warming trend over the entire Tibetan Plateau (Wang et al. 2012). The warming trend is more significant at higher elevations than lower elevations, especially in winter and spring (Liu et al. 2009). The climate model results also show that, on long-term time scale, the most notable feature over the Tibetan Plateau is the significant warming trends in both mean and extreme surface air temperature (Liu et al. 2006). At the same time, there are researches about the elevation dependency of warming in other mountainous regions. For example, Fan et al. (2011) found that temperature increases most pronouncedly in the southern and northwestern (high-elevations) parts of the Yunnan Plateau. Revadekar et al. (2013) revealed that the diurnal temperature range, which decreases in most parts of globe, has the increasing trends over many high-altitude stations in South Asia. Throughout the country, Fang (1992) found that the effect of latitude and altitude on temperature exhibits seasonal variation: Latitude is more important in winter, and altitude is more important in summer, but longitude has little influence. Lu et al. (2008) obtained similar results by using observed temperature data for last 52 years. Király and Jánosi (2005) found that the correlation coefficient of temperature tendency–latitude decreases with increasing distance from equator and proved that latitude is a dominant factor over Australia. On spatial distribution of temperature trends in China, except Sichuan Basin and the north of Yunnan Plateau, the warming trend exists in most regions, especially in northern and northeastern China (Chen et al. 1998; Ren et al. 2005).

Because of the complex topography, the climate change is far from uniform. Recent studies have investigated the impact of topography on the climate change. Liu et al. (2009) found that altitude dependency is most likely caused by the combined impact of cloud-radiation and snow-albedo feedbacks. Revadekar et al. (2013) examined trends of temperature extremes over South Asia and suggested that high-altitude sites appear to be more influenced by local factors. In addition, temperature trend subjects to other factors, such as changes in free atmosphere and effects of urbanization (Pepin and Lundquist 2008). It is generally accepted that altitude significantly influences the spatial distribution of temperature in highland areas. Since 1950s, most studies about temperature trend concentrated on the characteristics of horizontal distribution in China but seldom on the vertical distribution. This article uses observations to demonstrate the spatial features of the temperature trend as well as its seasonal characteristics, explores whether its relation with altitude is significant, and explores preliminarily the causes.

The rest of this paper is organized as follows: "Section 2" introduces data and methods. "Section 3" shows the distribution of temperature trend and the temperature trend–altitude relation. The possible physical processes are discussed in "Section 4." "Section 5" gives a brief summary.

2 Method and data

The dataset from 839 meteorological stations with daily temperature data from 1963 to 2012 is provided by the National Climatic Center of the China Meteorological Administration. To guarantee data quality, the stations with missing data in more than 3 months were removed. Ultimately, data collected from 745 stations were analyzed. The distribution of 745 weather observation sites with respect to altitude in China is shown in Fig. 1, located from near sea level to 4,800 m, from 16°N to 53°N and 75°E to 135°E.

The spatial distribution of temperature tendency was mapped by the software of ArcGIS. The analysis can be accomplished by the use of packages such as ArcGIS Geostatistical Analyst, which offers a range of facilities for smoothing data and exploring data variability and spatial correlation (Peng et al. 2011). In this paper, the ordinary kriging was selected as one of the interpolation methods. Kriging is a geostatistical method that generates or interpolates a probability surface that fits best to a scattered set of point values in two-dimensional space, involving an interactive investigation of the spatial behavior of the point value. The best estimation method is selected to map the output surface. And ordinary Kriging is the most general and widely used of the Kriging method.

Simple linear regression was used to calculate the temperature tendency rate, $x_t=a_0+a_1 t$, where a_0 is the intercept, a_1 is the slope, t is the year from 1963 to 2012, and x_t is the estimated temperature by the linear regression. The temperature tendency rate is $b=a_1\times 10$. The magnitude of b value is response rate. In addition, the correlation coefficient means the association between t and x_t. The linear trends were estimated by using ordinary least squares. The statistical significance of the linear trends is tested by using the Student's t test (Santer et al. 2000).

Following the method in Yang et al. (2011), observation sites are classified with the altitude change of every 10 m (e.g.,

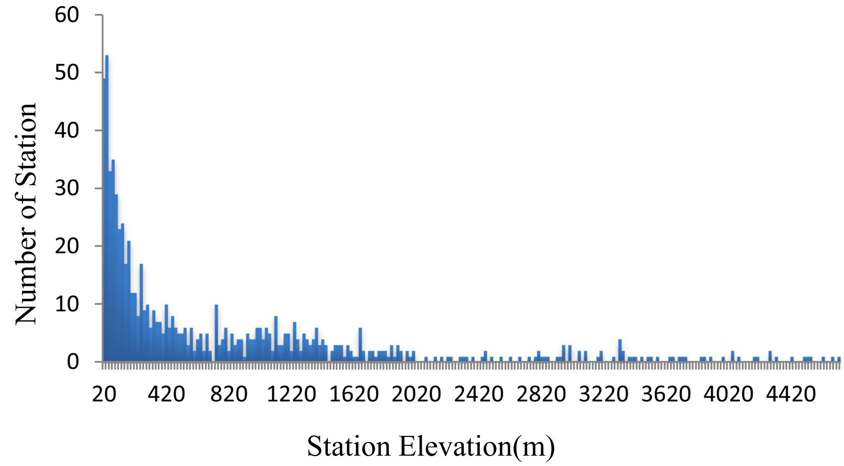

Fig. 1 Numbers of national meteorological stations at different altitude

the altitude below 10, from 10 to 20, from 20 to 30 m, respectively). To facilitate the discussion of the elevation dependency of climate warming, different elevation zones are divided according to running *t*test. The running *t*test is performed with a sliding window of 100 m. The results showed an abrupt shift around 200 m, exceeding the 99 % significance level (Fig. 2). Although there is no jump point at 2,000 m, most stations are below 2,000 m, while stations above 2,000 m are mainly located in the Tibetan Plateau (Wang et al. 2012). Figure 3 is the spatial distribution of stations divided by 200 m and 2,000 m. In the high-altitude, the stations are scattered, especially on the Tibetan Plateau, where almost all stations are above 2,000 m. The altitudes of the most regions of the Northeast, Inner Mongolia, and parts of the Northwest are from 200 to 2,000 m. The region below 200 m includes the southern of northeastern China, the eastern North China, the Yangtze-Huaihe River basin, and the southwestern of China.

The winter, spring, summer, and autumn mean respectively denote the 3-month average of the following: December-to-February, March-to-May, June-to-August, and September-to-November (Wu and Yang 2013).

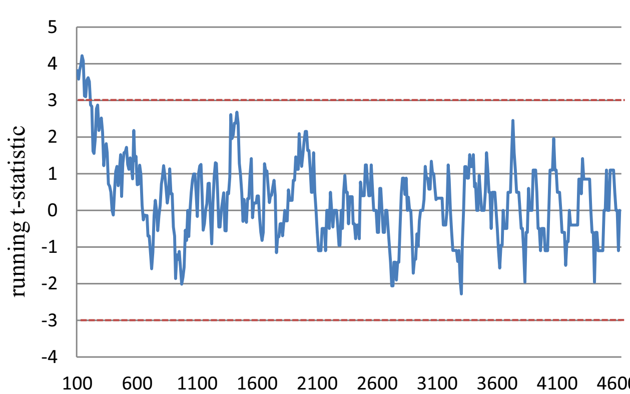

Fig. 2 Moving *t*test technique graph of dividing sequence by meteorological station elevations

3 Results

3.1 Temperature characteristics

The statistical results of network stations generally exhibit warming trend. The average annual temperature trend has a magnitude of 0.26 °C/decade, and 94 % of the network stations reach the 5 % significance level (Table 1). Considering the seasonal characteristics, warming occurs in all seasons, more remarkable in winter and autumn than in the other two seasons. The temperature increases most significantly in winter, up to 0.38 °C/decade, and most stations experience warming. In summer, the number of warming stations reaches minimum, and the number of cooling stations reaches maximum (accounting for 12 %). On the other hand, although the number of cooling stations reaches minimum in winter (only accounting for 1 % of the total stations), the temperature reduction has a maximum rate of −0.14 °C.

Figure 4 shows the spatial distributions of annual and seasonal temperature tendency. In general, significant warming is found in the whole country, but the magnitudes of warming are different in different region. Figure 4a shows the spatial distribution pattern of the temporal trends in annual mean temperature. Apparently, the temperature increase in South of the River and South China is much less than that in the Inner Mongolia, the northern part of Northeast China, the Northwest China, and the northern part of North China where the altitude is above 200 m and the warming is more significant north of 35°N. The majority of stations in Tibetan Plateau with altitude exceeding 2 km exhibit a slight warming. However, significant cooling trend is found in the Southwestern China. The statistical results for spring, summer, autumn, and winter are shown in Fig. 4b–e, respectively. In spring, the air temperature cools over the Sichuan Basin while warms in the rest of country, with the maximum in the Northeast. In summer, the most notable feature is the cooling maximum in the western part of the southern Yangtze River.

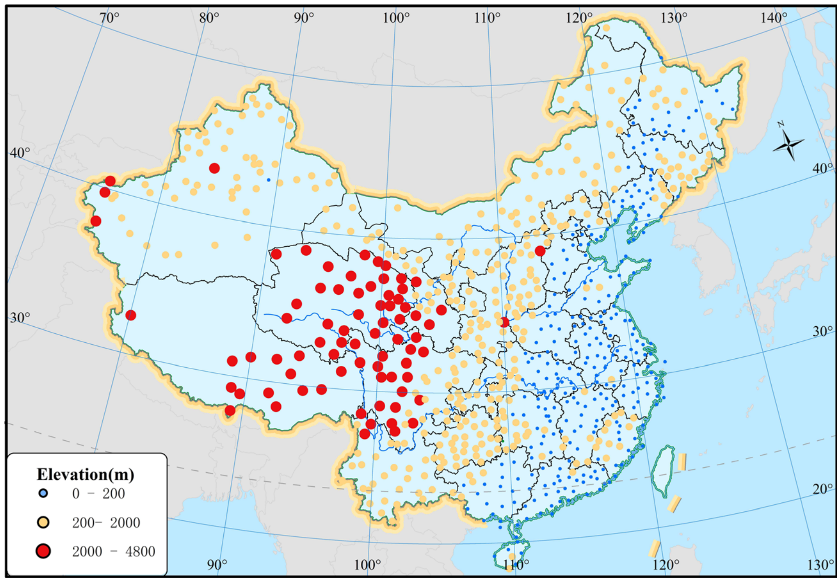

Fig. 3 Distribution of 745 stations divided by 200 and 2,000 m China. The *blue*, *yellow*, and *red solid circles* represent the points below 200, 200–2,000, and above 2,000 m, respectively

In autumn, the cooling region extends from the north China to Northern Hubei. Unlike the aforementioned seasons, the rest of the country with warming trend has a significant increase, and the maximums are located in Inner Mongolia, the northwest, and northeast in winter. The strongest warming is found during the winter and autumn, especially the winter. The seasonal features of the temperature trend are consistent with the results in Chen et al. (2002). The temperature change is of strong seasonality: a warming trend in winter and a cooling trend in summer.

According to the spatial distribution of temperature trend, we discuss the dominant factors: altitude or latitude. Zhai and Ren (1997) found that climate sensitivity generally increases in high latitudes, especially north of 35°N, due to the influence of changes in albedo and energy budgets. Lu et al. (2008) proposed that, among the factors which affect the temperature trend, topography is dominant in summer, and latitude is dominant in winter. This explanation is applicable in this study. Figure 4e presents contours of temperature trends in winter in step with lines of latitude. Although there are closed contours in Tibetan Plateau, the impact of topography on temperature trend in winter is relatively small. Whether for the seasonal or interannual variations, the Tibetan Plateau, whose altitude is mainly above 2,000 m, is the most notable warming area. In combination with the results in Wu et al. (2005) who indicated that temperature trend has been increasing by 0.24 °C/decade in Tibetan Plateau during 1971 to 2000, most stations at high altitudes show significant durative warming trends (Wang et al. 2012).

Table 1 Numbers of stations and temperature trends on an annual and seasonal basis

Time period	Warming		Cooling	
	Number	Temperature trend (°C/10a)	Number	Temperature trend (°C/10a)
Annual	730	0.26	15	−0.09
Spring	701	0.26	43	−0.08
Summer	657	0.21	88	−0.08
Autumn	729	0.26	16	−0.09
Winter	737	0.38	8	−0.14

3.2 Temperature trend–altitude relationship

The main geographical causes of temperature distribution in our country are latitude, altitude, and land–sea distribution (Fang 1992). Temperature trends of all 745 stations are respectively related with their latitude and longitude, as seen in Fig. 5. The relationship between temperature trend and latitude is positive, exceeding the 99 % significance level (Fig. 5a). However, a negative relationship between temperature trend and longitude is found in Fig. 5b, but it is insignificant. However, the numbers of stations in East or West China are different. In order to further prove the little influence of longitude, stations from 75°E to 135°E are classified with the longitude change of every 10° (e.g., the longitude from 75°E to 85°E, 85°E to 95°E, respectively). Then we calculated the average of temperature trend and the linear regression between temperature and longitude (Table 2). The absolute values of slope are very small, and the average of temperature tendency rates at different longitude ranges does not show obvious change. Therefore, annual temperature tendency rates do not significantly vary with longitude not only in every longitude ranges, but also the different longitude ranges. Some previous studies have proved this. Fang (1992) considered that effect of the distance from coast is unclear and local. On seasonal mean features, the dominant factors of

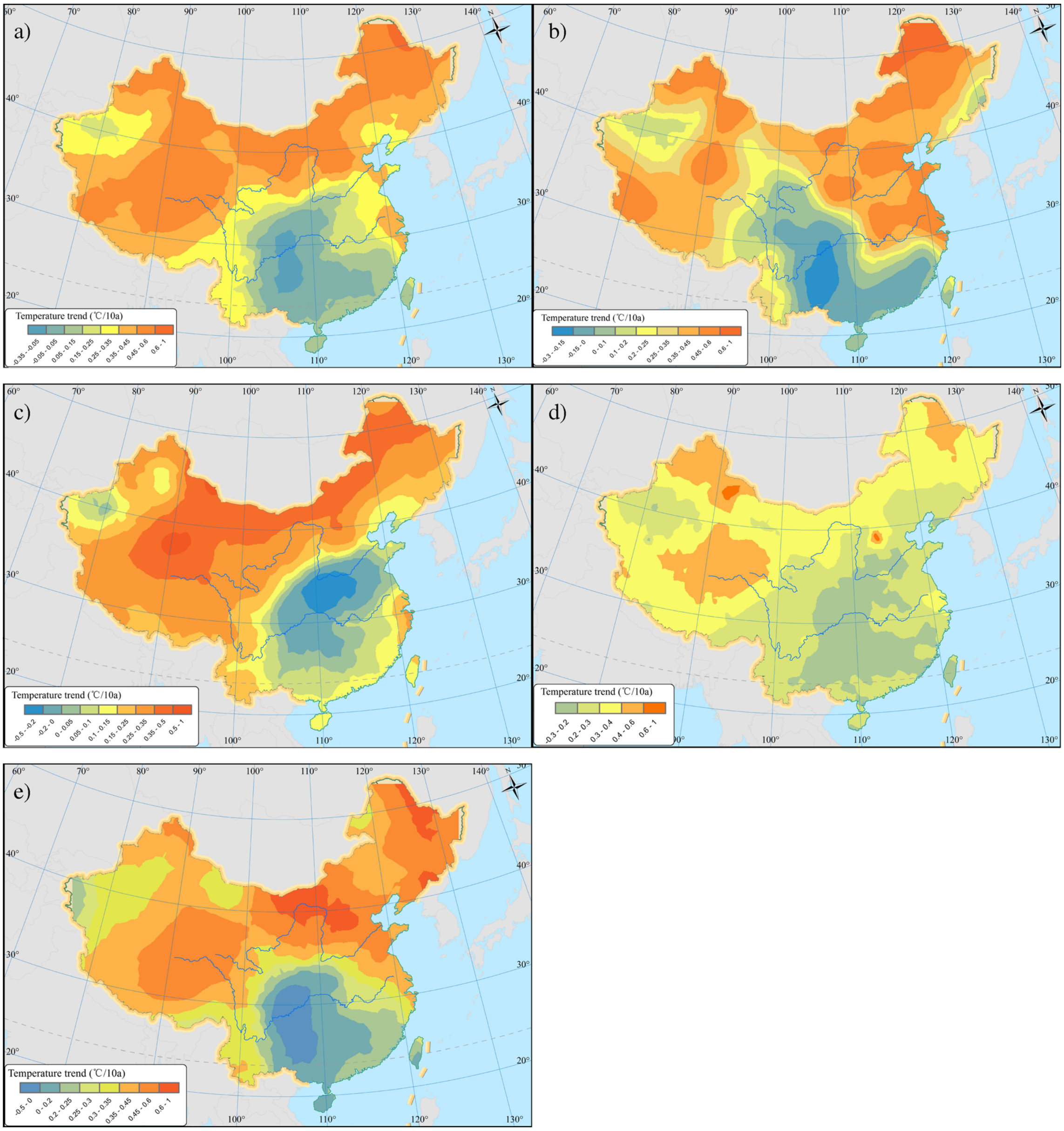

Fig. 4 Distribution of average temperature trend in China for the period of 1963–2012. **a**, **b**, **c**, **d**, and **e** are the results of annual, spring, summer, autumn, and winter mean, respectively

controlling temperature distribution in China are latitude and topography (Lu et al. 2008). Therefore, in the following, only the effect of latitude needs to be eliminated when analyzing the relationship between temperature trend and elevation. To ensure the minimum sample number being not less than 30, relationships between temperature trend and elevation are

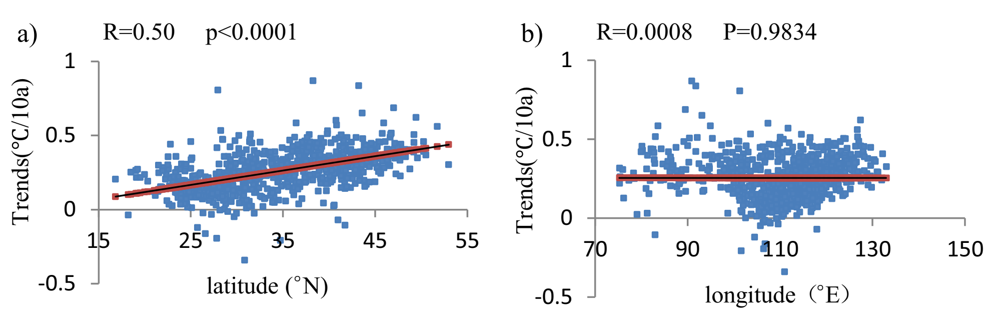

Fig. 5 Trend magnitudes of temperature versus latitude and longitude. *R* stands for correlation coefficients for the relationships and *P* for the statistical significance

Table 2 Temperature trend (°C/10a) at different longitude ranges

Longitude(°E)	75–85	85–95	95–105	105–115	115–125	125–135
B	0.01	0.01	−0.02	0.01	0.01	−0.003
R	0.23	0.17	0.36[a]	0.21[a]	0.36[a]	0.07
Average of trends	0.3	0.35	0.26	0.2	0.27	0.35
Number of sites	31	47	116	274	228	48

R and B represent the correlation coefficient and the slope of linear regression, respectively
[a] Represents significance 99 % level

analyzed at different latitudinal zones with 3.5° intervals. Moreover, stations are divided into three subregions with elevation: below 200, from 200 to 2,000, and above 2,000 m. According to this, temperature trends are shown in Fig. 6, from low to high elevation ranges and from south to north. In the south of 25.5°N, with each 1,000 m increase of altitude, temperature tendency rate decreases by 0.65 °C/decade below 200 m and increases by 0.09 °C/decade from 200 to 2,000 m (Fig. 6a and b). The same applies to the range of latitude from 25.5°N to 29°N. With the altitude increasing every 1,000 m, temperature tendency rate increases by 0.7 °C/decade below 200 m and decreases by 0.05 °C/decade from 200 to 2,000 m. Compared with other latitudes, the amplitude of temperature trend between 29°N and 32.5°N is the largest. We note that the magnitudes from 200 to 2,000 m are one order smaller than those below 200 m. Toward to the north region, especially north of 36°N, the amplitude of annual temperature tendency rates do not significantly vary with altitude but increases for the entire region. This may be caused by less stations below 200 m south of 36°N, which leads to the inaccuracy of data analysis and the effect of latitude. Currently, some studies on the variation of temperature and precipitation with latitude have divided the China into north–south districts based on 35°N (Lu et al. 2006; Yang et al. 2011).

3.3 Seasonal features of temperature trend–altitude relationship

Figure 6 shows the relationship between annual temperature trend magnitudes at individual surface stations and altitude, together with their linear regression equations. Positive relationships are shown at the altitude from 200 to 2,000 m and negative ones below 200 m, especially south of 36°N (Fig. 6a–h). North of 39.5°N, negligible opposite relationships are seen at these altitude ranges. There is a slight positive correlation between elevation and the trend magnitude above 2,000 m, but the correlation coefficient is weak (Fig. 6o).

To show the relationship between seasonal temperature trend and altitude, we calculated the linear regression for annual and seasonal temperature variations at different altitudinal ranges (Table 3). A positive value indicates the temperature trend magnitudes at individual stations increasing with altitude, and a negative value indicates those decreasing with altitude. Table 3 shows that, whether for seasonal or annual characteristics, there are opposite temperature trend–altitude relations at different altitude ranges, especially south of 32.5°N. At the latitudes from 29°N to 32.5°N, corresponding to each 1,000 m increase of altitude, the temperature trend rate reaches a peak descent rate of 1.2 °C/decade and reaches a peak ascent of 0.16 °C/decade below 200 m. In contrast with different seasonal statistical results, temperature trends of the stations south of 32.5°N display significant correlation with altitude, especially in winter and spring, mostly exceeding the 99 % significance level. At altitude from 200 to 2,000 m, correlations reach the 95 % significance level mostly in autumn and winter. Generally, the largest negative mean trend magnitudes of temperature trend–altitude emerge in spring and the largest positive ones, in winter. Above 2,000 m, in addition to a negative value in summer, there exist small increasing trend and weak positive correlations. This apparent difference suggests that other factor affects the temperature trends in different altitudes.

4 Discussion

In this section, we would like to provide a discussion on the physical mechanisms.

Temperature trends in China are similar to global change over recent 50 years, except in southwest China. There exists a cooling center in Southwest all year round. Some researches showed that the climate in southwest China is led by the influence of the Tibetan Plateau. For example, Li et al. (2008) found that mean temperature and highest temperature of Southwest China are more sensitive to vegetation change over Tibetan Plateau. Besides, Zhou et al. (2010) considered that the winter snow cover in the plateau is an important index for forecasting summer precipitation over Southwest China. Li et al. (2005) found that the March–April cooling shift on the lee side of the Tibetan Plateau is associated with the North Atlantic Oscillation. The increased clouds caused by enhanced westerlies passing over the Tibetan Plateau during positive NAO phases would induce a negative net cloud-radiative forcing. On the other hand, some researches indicate that the formation of cooling center is more likely due to the radiative effect caused by increasing concentrations of aerosol. The movement of cooling center may be associated with the transport of aerosols under the prevailing wind-forcing (Wang et al. 2010). In addition, due to the rapid economic development of regional scale and increasing pollution emissions, aerosols of anthropogenic origins would have

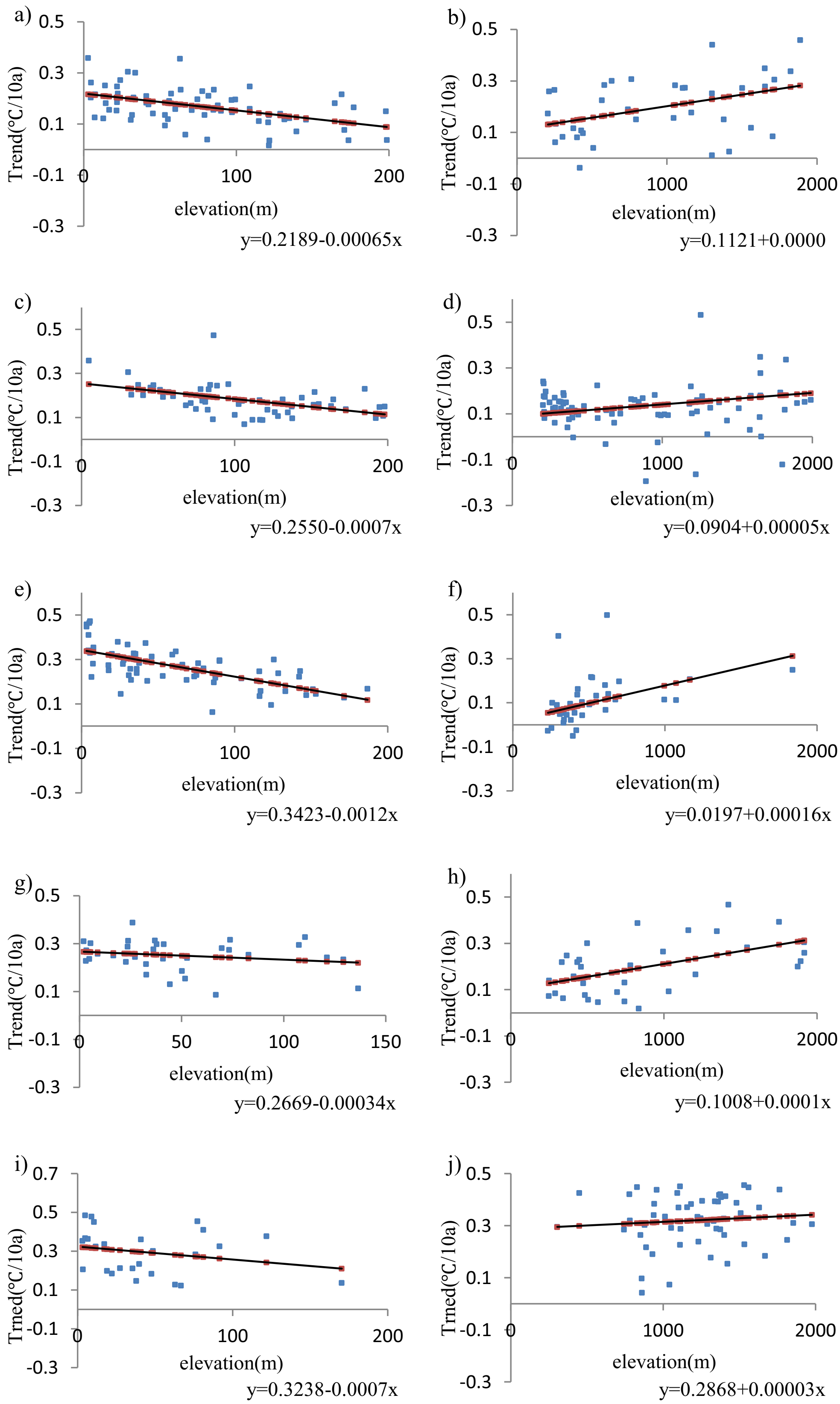

Fig. 6 Trend magnitudes of temperature (°C/10a) versus elevation, using OLS methods. **a**, **c**, **e**, **g**, **i**, **k**, **m** are the results of the elevations below 200 m; **b**, **d**, **f**, **h**, **j**, **l**, **n** the elevations between 200 and 2,000 m; **o** the elevations over 2,000 m. **a** and **b**, in the south of 25.5°N; **c** and **d**, 25.5–29°N; **e** and **f**, 29–32.5°N; **g** and **h**, 32.5–36°N; **i** and **j**, 36–39.5°N; **k** and **l**, 39.5–43°N; **m** and **n**, in the north of 43°N

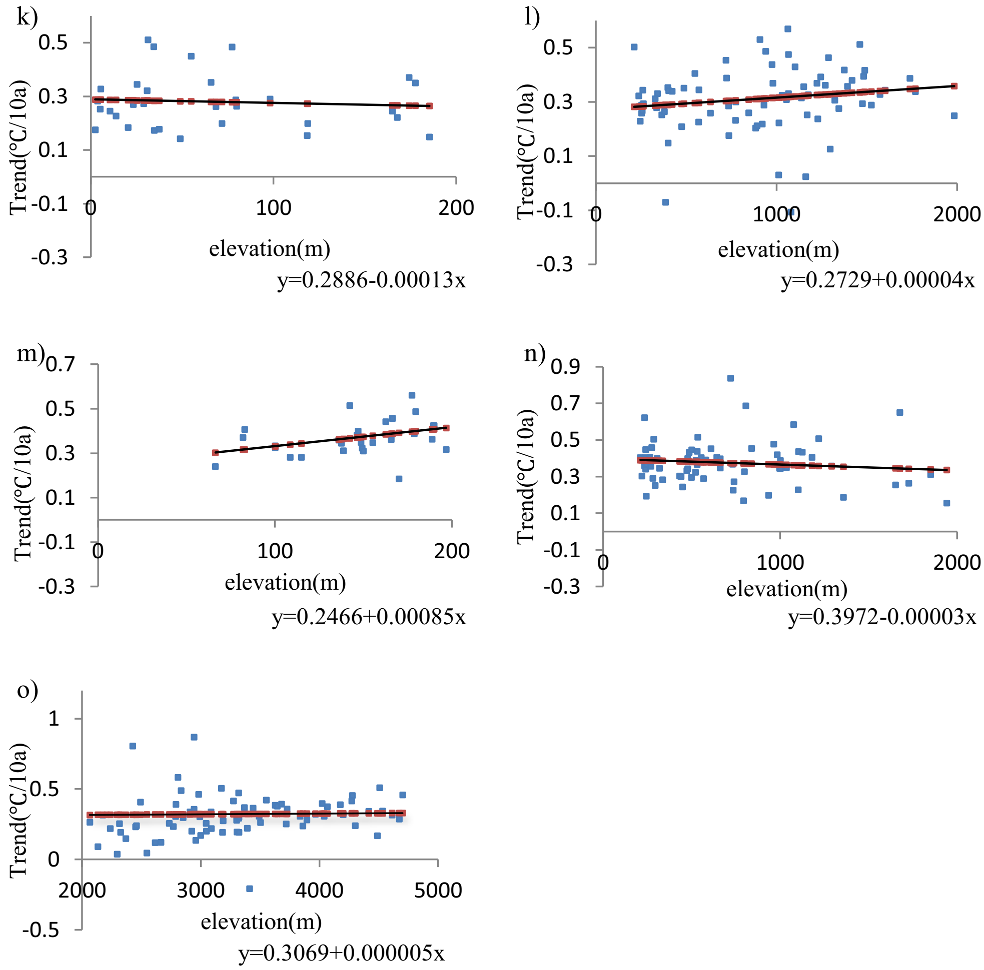

Fig. 6 (continued)

significant climatic impact, especially over East Asia (Huang et al. 2007). Moreover, China is the largest contributor to global sulfur dioxide emissions. Sulfate aerosols can suppresses the signal of global warming by increasing cloudiness that prevents solar radiation to the surface (Thompson et al. 1997). Qian and Giorgi (2000) observed a significant cooling trend in the Sichuan Basin in accordance with increasing atmospheric aerosol.

In our study, the different relationships between temperature trend and elevations at different altitude ranges may be the result of combined complex topographical and other local effects. Figure 6 suggests that the relationships between temperature trend and elevation display differences in different zones, more significant in the south than north, probably due to aerosol and urbanization effect. The main geographical factors controlling the spatial distribution of annual-mean aerosols are population density, elevation, and vegetation coverage (Zheng et al. 2012). Because of the general increasing continentality with latitude in China, the temperature change in higher-latitude region is more sensitive to global change than the lower latitude region. Temperature increases more in North, caused by the dominance of latitude effect over the cooling effect of sulfate aerosol. In addition, the gathering of sulfate aerosols is influenced by different terrains between the southern and northern China, such as the land cover change in the north China driven by desertification (He et al. 2005). Below 200 m, most stations are located in the southeast of China, and the number of stations increases with altitude. These regions experience rapid urbanization (Zheng et al. 2012), leading to increase of anthropogenic aerosols. This is in agreement with Chen et al. (2009) who found that inferred aerosol optical depths exhibit two maximums over Sichuan Basin and Yangtze River Delta. Furthermore, by analyzing global direct and diffuse solar radiation data of stations in Shanghai, Nanjing, and Hangzhou, Zhang et al. (2004) found that a decrease in direct radiation total and a slight increase in diffuse radiation in eastern China. These phenomena may be caused by effect of greenhouse gases, the increase in air pollution, and decrease in relative sunshine (He et al. 2005; Zhang et al. 2004). Therefore, temperature tendency rates of stations below 200 m which show significant urbanization effect decrease with altitude.

Table 3 Correlation coefficient (r) between elevation and temperature trends in different latitude ranges classes on an annual and seasonal basis

		Spring		Summer		Autumn		Winter		Annual	
Latitude (°N)	Elevation (m)	$a\times10^{-3}$	r	$a\times10^{-3}$	r	$a\times10^{-3}$	r	$a\times10^{-3}$	r	$a\times10^{-3}$	r
16–25.5	0–200	−0.72	0.55[a]	−0.59	0.48[a]	−0.68	0.36[a]	−0.64	0.41[a]	−0.65	0.48[a]
	200–2,000	0.13	0.44[a]	0.04	0.23	0.04	0.27	0.13	0.45[a]	0.09	0.41[b]
25.5–29	0–200	−1.20	0.60[a]	−0.66	0.32[b]	−0.66	0.39[a]	−0.61	0.38[b]	−0.71	0.48[a]
	200–2,000	−0.08	0.35[a]	0.05	0.38[a]	0.04	0.32[a]	0.05	0.32[a]	0.05	0.38[b]
29–32.5	0–200	−1.39	0.67[a]	−1.29	0.55[a]	−1.20	0.60[a]	−1.02	0.62[a]	−1.20	0.68[a]
	200-2,000	0.18	0.39[a]	0.14	0.33	0.12	0.30	0.22	0.44[a]	0.16	0.38[b]
32.5–36	0–200	0.21	0.10	−0.39	0.23	−0.60	0.29	−0.68	0.32	−0.34	0.20
	200–2,000	−0.01	0.05	0.11	0.83[a]	0.07	0.70[a]	0.04	0.33[b]	0.11	0.52[a]
36–39.5	0–200	−0.81	0.27	−0.97	0.37	−0.22	0.08	−0.27	0.08	−0.65	0.24
	200–2,000	−0.11	0.40[a]	0.15	0.40[a]	0.05	0.31[b]	−0.05	0.11	0.03	0.09
39.5–43	0–200	−0.50	0.31	0.03	0.02	−0.14	0.06	0.19	0.06	−0.13	0.07
	200–2,000	0.02	0.08	0.07	0.27[b]	0.06	0.24[b]	−0.09	0.25[b]	0.04	0.15
43–53	0–200	1.08	0.57[a]	0.69	0.35	0.77	0.40[b]	0.80	0.20	0.85	0.37[b]
	200–2,000	−0.01	0.04	0.03	0.08	0.01	0.03	−0.11	0.27[b]	−0.03	0.13
27–39	2,000–4,800	0.006	0.02	−0.01	0.05	0.005	0.02	0.02	0.07	0.003	0.01

[a] Significant at the 99 % confidence level
[b] Significant at the 95 % confidence level

On the other hand, high elevation sites are closer to free atmosphere where there is less effect of anthropogenic factors such as urbanization and pollution (Revadekar et al. 2013). Beniston and Rebetez (1996) found that high elevation records show more significant interannual climatic signals where possible greenhouse-gas warming would presumably be detected with more clarity. The change over highlands above 2,000 m is a good indicator for global warming, and the exposed mountain summits show more spatially consistent temperature trends because of the increasing influence of the free-air (Pepin and Lundquist 2008). Therefore, increases of warming rates with altitude from 200 to 2,000 m are consistent with the result of global warming. Most stations above 2,000 m are located in the Tibetan Plateau, whose positive feedback of ice or snow albedo reinforces warming at high-altitude. High spatial resolution model results suggested that snow-albedo and cloud radiation feedbacks are the main physical causes of the elevation dependency of climate warming (Liu et al. 2009). At the same time, because of global warming, alteration of the glacier, snow cover, and permafrost lead to desertification of lakes and rivers of the Tibetan Plateau. Thus, to a certain extent, the resultant dust aerosols suppress the warming in the Tibetan Plateau.

5 Summary

This study revealed surface warming and its elevation dependency by using daily temperature data from 745 meteorological stations in China during 1963–2012. We calculated the temperature trends for individual station and then summarized trends for three elevation zones at different latitudes. It is found that there is a general warming trend in agreement with global warming, with the warming rate of 0.26 °C/decade. The Inner Mongolia, the northern part of Northeast China, the Northwest Territories, and the northern part of North China, whose altitudes are higher than 200 m, exhibit a maximum of warming rate. The temperature increases most rapidly in winter, up to 0.38 °C/decade and the least in summer. In addition, there exists an obvious cooling center in Sichuan Basin, and the cooling moves with the seasons.

No consistent elevation–warming trend relation is found on national scale. The relationship is analyzed by dividing China into three subregions: below 200, 200–2,000, and above 2,000 m. Interestingly, we found that the temperature trend–altitude relations are different among the three regions. The temperature tendency decreases below 200 m and increases from 200 m to 2,000 m with altitude, especially pronounced south of 36°N. And a weak positive temperature trend–altitude relation is found over 2,000 m. Further analysis shows that magnitudes from 200 to 2,000 m are one order lower than those below 200 m. Larger and more consistent warming is found in winter at high latitude, especially north of 36°N. In summer, the relationships between temperature trend and altitude are weaker, and there is an obvious cooling center.

Above 2,000 m, the main physical mechanism of elevation dependency of warming may be snow-albedo and cloud radiation feedbacks. The combined effects of aerosols and urbanization lead to an opposite relation below 200 and 200–2,000 m. Although human activities have a greater impact on temperature trends locally and regionally, latitude and topography are the primary factors that affect the warming pattern in China.

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