Postprint: Climatic Change Characteristics of Extreme Warming Processes in the Eastern Pamir Plateau, 1961–2017

Authors: Mao Weiyi

Date: 2019-11-14T00:00:00+00:00

Abstract

Using daily maximum temperature data from three meteorological stations (Tashkurgan, Turugart, and Wuqia) from January 1, 1961 to December 31, 2017, a database of single-station warming processes was established for the eastern Pamir Plateau at the northern end of the China-Pakistan Economic Corridor. Extreme warming processes were selected using the percentile method based on comprehensive intensity, and the climatic change characteristics of frequency and intensity of extreme warming processes at the three stations including Tashkurgan in this region were comparatively analyzed. The results show: From 1961 to 2017, a total of 489 extreme warming processes occurred in Tashkurgan on the eastern Pamir Plateau, with an average of 8.6 events per year. The extreme warming processes in Tashkurgan lasted an average of 3.6 d, with those lasting 3 d being the most frequent, accounting for 24.7%. Turugart and Wuqia were dominated by extreme warming processes lasting 2–3 d. Extreme warming processes in Tashkurgan occurred most frequently in July, in Turugart in May, and in Wuqia in January. The most intense warming process in Tashkurgan in terms of comprehensive intensity occurred on February 20–21, 2008. The comprehensive intensity of extreme warming processes at the three stations on the eastern Pamir Plateau was strongest in winter.
Over the past 57 years, the annual frequency of extreme warming processes in Tashkurgan on the eastern Pamir Plateau showed a significant linear increasing trend, with a rate of increase of 0.57 events · (10 a) ^{1}. Since entering the 21st century, extreme warming processes have occurred relatively frequently, with intensified interannual variability. The linear trends for Turugart and Wuqia were not significant. Over the past 57 years, the intensity of extreme warming processes in Tashkurgan showed a significant linear strengthening trend, with the amplitude of interannual variation intensifying in recent years. The process intensity in Wuqia showed a slight decreasing trend, with the amplitude of interannual variation tending to stabilize in recent years. In summary, extreme

warming processes occurred most frequently in July in Tashkurgan. Over the past 57 years, the annual frequency of extreme warming processes has increased significantly and their intensity has strengthened significantly. In recent years, the interannual variation amplitude of both frequency and intensity of extreme warming processes has intensified, leading to frequent occurrences of ice (snow) melt floods and their derivative geological disasters in the northern region of the "China-Pakistan Economic Corridor" on the eastern Pamir Plateau, with disaster risks escalating.

Full Text

Preamble

Change Characteristics of Extreme Temperature-Rising Process in the East Pamirs during 1961–2017

MAO Weiyi[1,2], YAO Junqiang[1,2], CHEN Jing[1,2], LI Shujuan[1,2], LI Hongjun[1,2], SHEN Yongping[3]

(1. Institute of Desert Meteorology, China Meteorological Administration, Urumqi 830002, Xinjiang, China;
2. Center of Central Asia Atmospheric Science Research, Urumqi 830002, Xinjiang, China;
3. Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences, Lanzhou 730000, Gansu, China)

Abstract: Single-station databases of temperature-rising process at three meteorological stations including Taxkorgan, Turgart, and Wuqia in the east Pamirs were established using daily maximum temperature data from January 1, 1961, to December 31, 2017. Three databases of extreme temperature-rising process were selected using the percentile method of comprehensive intensity. The change characteristics of frequency and intensity of extreme temperature-rising process at the three stations were compared and analyzed. The results showed that: (1) There were totally 489 extreme temperature-rising processes, with an annual average of 8.6 times at Taxkorgan Meteorological Station in the east Pamirs from 1961 to 2017. At Taxkorgan, the average duration of extreme temperature-rising process was 3.6 days, with the highest occurring frequency of 3-day duration accounting for 24.7% of the total. The 2–3 day duration was dominant at Turgart and Wuqia. The extreme temperature-rising process occurred most frequently in July at Taxkorgan, in May at Turgart, and in January at Wuqia; (2) The extreme temperature-rising process with the strongest comprehensive intensity at Taxkorgan occurred during February 20–21, 2008. The comprehensive intensity of extreme temperature-rising processes was strongest in winter at the three stations in the east Pamirs; (3) In recent 57 years, the annual frequency of extreme temperature-rising process showed a significant linear increasing trend, with a decadal increase rate of 0.57 times at Taxkorgan. The extreme temperature-rising process was relatively frequent from the begin-

ning of the 21st century, and the interannual variability was intensified. The linear trend of annual frequency of extreme temperature-rising processes was not significant at Turgart and Wuqia; (4) In recent 57 years, the intensity of extreme temperature-rising process showed a significant linear increasing trend, and the interannual variation was intensified in recent years. The intensity of extreme temperature-rising process was slightly decreased, and the range of interannual change was decreased in recent years at Wuqia. In a word, at Taxkorgan, the extreme temperature-rising process occurred most frequently in July. The frequency and intensity of extreme temperature-rising process increased significantly at Taxkorgan in past 57 years, and the interannual variation intensified in recent years. Ice-snow melting floods and their derivative geological hazards occurred frequently along the northern section of the "China-Pakistan Economic Corridor" in the east Pamirs.

Keywords: extreme temperature-rising process; frequency; intensity; climate change; Pamirs

1. Introduction

According to the IPCC Fifth Assessment Report, global warming has become an indisputable fact, with significant increases in extreme temperature events worldwide. The Pamir Plateau, known as the "Roof of Central Asia," is particularly sensitive to climate change. Studies have shown that temperature rise in this region has led to accelerated glacier melting, increased frequency of snow disasters, and enhanced risks of glacial lake outburst floods and debris flows, posing serious threats to the China-Pakistan Economic Corridor.

Previous research on extreme temperature events in Xinjiang has primarily focused on absolute thresholds and percentile-based methods. However, the temperature-rising process—a critical factor triggering snowmelt floods and glacial hazards—has received limited attention. The comprehensive intensity index (IZ) provides a more holistic measure, incorporating both temperature amplitude and duration. This study establishes databases of extreme temperature-rising processes at three meteorological stations in the east Pamirs (Taxkorgan, Turgart, and Wuqia) using daily maximum temperature data from 1961–2017, and analyzes their frequency and intensity characteristics.

2. Data and Methods

2.1 Data Source

Daily maximum temperature data from January 1, 1961, to December 31, 2017, were obtained from three national meteorological stations in the east Pamirs: Taxkorgan (37°47 N, 75°14 E, 3093.7 m), Turgart (40°31 N, 75°24 E, 3507.2 m), and Wuqia (39°43 N, 75°15 E, 2177.5 m). The data quality was strictly controlled, and missing values were interpolated using linear regression.

2.2 Definition of Extreme Temperature-Rising Process

A temperature-rising process is defined as a period when the 24-hour temperature change (ΔT) exceeds 0.0°C. The process begins when ΔT > 0.0°C and ends when ΔT 0.0°C for two consecutive days. The comprehensive intensity index (IZ) is calculated as:

$$IZ = IF + IT_{24} + IT_G + IJP$$

where IF is the initial temperature intensity, IT is the 24-hour temperature change intensity, IT_G is the process 持续性 intensity, and IJP is the cumulative intensity. The 90th percentile of IZ values is used as the threshold for selecting extreme temperature-rising processes.

2.3 Intensity Classification

Extreme temperature-rising processes are classified into five intensity levels based on the IZ index: weak (below 57th percentile), moderate (57th–75th), strong (75th–90th), stronger (90th–95th), and strongest (above 95th). The threshold for extreme events is set at the 90th percentile, corresponding to IZ 10% of all processes.

3. Results

3.1 Frequency Characteristics

3.1.1 Annual Frequency Variation From 1961–2017, Taxkorgan recorded 489 extreme temperature-rising processes, with an annual average of 8.6 events. The frequency showed significant interannual variability, with the highest values occurring in 2011 (19 events) and 2016 (19 events). The linear trend indicates a significant increase of 0.57 events per decade ($p < 0.05$). The 21st century has witnessed notably higher frequency and enhanced interannual variability compared to previous decades.

shows the frequency distribution of extreme temperature-rising processes with sustained days at the three stations. At Taxkorgan, 3-day events were most common (24.7% of total), while Turgart and Wuqia were dominated by 2–3 day events.

3.1.2 Seasonal Distribution The seasonal distribution varies significantly among stations. Taxkorgan shows peak occurrence in July (10.6 events on average during 2011–2017), Turgart in May, and Wuqia in January. Winter months (December–February) account for 21% of events at Taxkorgan, while spring (March–May) is the dominant season at Turgart.

3.2 Intensity Characteristics

3.2.1 Comprehensive Intensity Analysis The strongest extreme temperature-rising process at Taxkorgan occurred on February 20–21, 2008, with IZ reaching 24.0. Winter processes generally exhibit the highest intensity across all three stations. The average intensity (IZ) shows a significant increasing trend at Taxkorgan (0.22 per decade, $p < 0.05$) and Turgart (0.18 per decade, $p < 0.05$), but a slight decreasing trend at Wuqia in recent years.

[Figure 9: see original paper] and [Figure 10: see original paper] illustrate the annual variation of average intensity (IZ) and maximum intensity (IZ) at Turgart and Wuqia. The interannual variation has intensified since 2000, particularly at Taxkorgan where the range of IZ has expanded.

3.2.2 Spatial Distribution The spatial analysis reveals that Taxkorgan experiences both the highest frequency and intensity of extreme temperature-rising processes. The decadal average IZ values are 5.0–5.3 across all stations, with maximum values reaching 8.1–8.2. The 21st century shows the most pronounced increase in intensity, coinciding with accelerated glacier retreat in the region.

4. Discussion and Conclusions

(1) From 1961–2017, Taxkorgan recorded 489 extreme temperature-rising processes with an annual average of 8.6 events. The average duration was 3.6 days, with 3-day events being most frequent (24.7%). Turgart and Wuqia were dominated by 2–3 day events. The processes occurred most frequently in July at Taxkorgan, May at Turgart, and January at Wuqia.

(2) The strongest extreme temperature-rising process at Taxkorgan occurred during February 20–21, 2008. Winter processes showed the highest intensity across all three stations. The intensity increased significantly at Taxkorgan and Turgart, with interannual variation intensifying in recent years.

(3) The frequency and intensity of extreme temperature-rising processes have increased significantly at Taxkorgan over the past 57 years, with enhanced interannual variability in recent decades. This trend correlates with increased ice-snow melting floods and geological hazards along the China-Pakistan Economic Corridor in the east Pamirs.

(4) The comprehensive intensity index effectively captures the characteristics of extreme temperature-rising processes. Further research should focus on the physical mechanisms linking these processes to cryospheric hazards and their impacts on regional infrastructure and water resources.

References

[1] SHEN Yongping, WANG Guoya. Key findings and assessment results of

IPCC WGI Fifth Assessment Report [J]. Journal of Glaciology and Geocryology, 2013, 35(5): 1068-1076.

[2] SHI Yafeng. Concise Glacier Inventory of Chinese [M]. Shanghai: Shanghai Science and Technology Popularization Press, 2005.

[3] SHI Yafeng, SHEN Yongping, HU Ruji. Preliminary study on signal, impact and foreground of climatic shift from warm-dry to warm-humid in Northwest China [J]. Journal of Glaciology and Geocryology, 2002, 24(3): 219-226.

[4] ZHANG Shuming, WANG Zhijie, YOU Pingda, et al. Research on Surface Water Resources in Xinjiang [M]. Beijing: China Water & Power Press, 2008.

[5] SHEN Yongping, SU Hongchao, WANG Guoya, et al. The responses of glaciers and snow cover to climate change in Xinjiang (I): Hydrological effects [J]. Journal of Glaciology and Geocryology, 2013, 35(3): 513-527.

[6] SHEN Yongping, SU Hongchao, WANG Guoya, et al. The responses of glaciers and snow cover to climate change in Xinjiang (II): Hazard effects [J]. Journal of Glaciology and Geocryology, 2013, 35(6): 1355-1370.

[7] ZHAI Panmao, REN Fumin. On changes of China's maximum and minimum temperatures in the recent 40 years [J]. Acta Meteorologica Sinica, 1997, 55(4): 418-429.

[8] REN Fumin, ZHAI Panmao. Study on changes of China' s extreme temperatures during 1951-1990 [J]. Chinese Journal of Atmospheric Sciences, 1998, 22(2): 217-227.

[9] KARL T R, KUKLA G, GAVIN J. Decreasing diurnal temperature range in the United States and Canada from 1941 through 1980 [J]. Journal of Climate and Applied Meteorology, 1984, 23(11): 1489-1504.

[10] ZHOU Yaqing, REN Guoyu. Variation characteristics of extreme temperature indices in mainland China during 1956-2008 [J]. Climatic and Environmental Research, 2010, 15(4): 405-417.

[11] Nuerlan Hazaz, Mahat Mulatibiek, Mahasat Hazihali. A flood in the Ertix River Basin in Xinjiang [J]. Arid Zone Research, 2013, 30(6): 981-985.

[12] MAO Weiyi, ZHANG Xu, YANG Zhihua, et al. Winter snowmelt flood in the northwest of Junggar Basin first monitored by satellite remote sensing [J]. Journal of Glaciology and Geocryology, 2010, 32(1): 211-214.

[13] MAO Weiyi, CHEN Pengxiang, SHEN Yongping. Characteristics and effects of the extreme maximum air temperature in the summer of 2015 in Xinjiang under global warming [J]. Journal of Glaciology and Geocryology, 2016, 38(2): 291-304.

[14] YE Dianxiu, YIN Jifu, CHEN Zhenghong, et al. Spatiotemporal change characteristics of summer heat waves in China in 1961-2010 [J]. Climate Change Research, 2013, 9(1): 15-20.

[15] WANG Jiaoyan, XIE Lei. Analysis on the change of flood and its formation causes in the Piliqing River Basin [J]. Arid Zone Research, 2011, 28(5): 756-760.

[16] MAO Weiyi, ZHANG Zulian. Climate characteristics of frequency and intensity for the temperature-rising processes in Urumqi during 1951-2015 [J]. Desert and Oasis Meteorology, 2016, 10(6): 11-18.

[17] ZHU Yingyan, YANG Zhiquan, LIAO Liping, et al. Glacial geomorphological geohazard along China-Pakistan International Karakoram Highway [J]. Journal of Catastrophology, 2014, 29(3): 81-90.

[18] ZHANG Zhen, LIU Shiyin, WEI Junfeng, et al. Monitoring a glacier surge in the Kungey Mountain, Eastern Pamir Plateau using remote sensing [J]. Progress in Geography, 2018, 37(11): 1545-1554.

[19] ZHANG Xuejing. Study on the distribution characteristics and control for geological disasters along International Karakoram Highway (KKH) [J]. Journal of Chongqing Technology and Business University (Natural Science Edition), 2013, 30(2): 45-50.

[20] SHEN Yongping, WANG Shunde, WANG Guoya, et al. Response of glacier flash flood to global warming in Tarim River Basin [J]. Climate Change Research, 2006, 2(1): 32-35.

Note: Figure translations are in progress. See original paper for figures.