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ORIGINAL PAPER

Evaluation of the tourism climate in the Hexi Corridor of northwest China's Gansu Province during 1980–2012

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Abstract As a pivotal section of the Silk Road in northwest China, the Hexi Corridor is a popular tourist destination. In this study, the tourism climate conditions in this region were discussed using the Physiologically Equivalent Temperature (PET) and the Climate-Tourism/Transfer-information-Scheme (CTIS) from 1980 to 2012. Overall, cold or cool stress was prevalent in the area, and the optimal travel period was from May to September. With global warming, the annual numbers of cumulative days with relatively cold conditions decreased, and the annual numbers of cumulative days with comfortable and relatively hot conditions increased. Two typical stations, Wushaoling and Dunhuang, were compared and analysed for their tourism climate information according to the frequency of PET and CTIS conditions, respectively. In addition, regional variations in the tourism climate conditions based on geographic information systems (GIS) were investigated during the optimal travel period.

1 Introduction

Tourism is a major economy sector in the world, which accounts for roughly 9.8 % of the world's gross domestic product (GDP) in 2014 (WTTC 2015). Similarly, tourism has significantly contributed to employment, attracted investors and increased the GDP of China. In 2014, the tourism industries in China provide 64 million jobs and account $117 billion in investments and $850 billion of the GDP directly or indirectly (Hu and Xie 2014). Climate is considered as an overwhelming dependent factor for tourism along with other natural resources, such as geographical location, topography, landscape, flora and fauna (de Freitas 2003; Matzarakis 2006). Climate affects tourism in various ways which can impact tourist participation in tourism and the tourist experiences. Good climate conditions generally increase tourist satisfaction, and poor climate conditions can disrupt outdoor activities (Yu et al. 2009). Additionally, climate is an important factor that influences where tourists choose to travel (Matzarakis et al. 2004; Matzarakis 2006), which can result in seasonality of tourism activities. The above-mentioned influences of climate on tourism could eventually impact the attractiveness and the tourism demand of tourist destinations (Goh 2012).

Climate change has emerged as a defining issue of the twenty-first century. The global average surface temperature increases by 0.85 °C from 1880 to 2012. The influences of climate change, including extreme weather events, are expected to result in significant risks to societies and ecosystems (IPCC 2014). Climate change influences tourism by changing the quality and quantity of tourist resources and altering the seasonality of tourism flows, which can result in the divergence in tourist markets and tourism destinations in general (Amelung et al. 2007). Global warming may result in a gradual shift of tourism destinations towards higher elevations and latitudes and increase the numbers of domestic trips in high-latitude countries (Jaume 2014).

Climate is an important resource for various forms of tourism that can be measured and evaluated. To quantitatively assess the effects of climate factors or climate change on tourism and human health, well-being and comfort in other social contexts, several research initiatives have considered numerical indexes within the last century. Many simple indexes including temperature, precipitation, effective temperature and temperature-humidity index have been used to address issues

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that link tourism and climate conditions (e.g. Lise and Tol 2002; Maddison 2001; Eludoyin et al. 2014). In addition, the physiologically equivalent temperature (PET) derived from the human energy balance has commonly been used to evaluate the effects of the thermal comfort component on tourism climate around the world (e.g. Matzarakis 2008; Matzarakis and Amelung 2008; Zaninovic and Matzarakis 2009; Matzarakis et al. 2012a, b). Another approach based on climate thresholds, the Climate-Tourism/Transfer-Information-Scheme (CTIS), integrated and simplified the detailed climate information including thermal comfort and physical as well as aesthetical conditions, which can be used to plan their tourism activities by tourists (Matzarakis 2013, 2014).

In China, researches regarding the connection between tourism and climate have developed rapidly and highlight the characteristics of tourism areas, including provinces, cities and scenic spots. Advanced evaluation methods from abroad have been used to assess the climate conditions of tourist destinations, study the relationships between the numbers of tourists and climate conditions, provide meteorological services for travellers and develop regional climatic tourism. The use of an appropriate index for tourism is one of the most important issues in tourism climate researches (Farajzadeh and Matzarakis 2012). However, the numerical indexes that are usually applied, such as the temperature-humidity index (THI), humidity index (H) and wind chill index (WCI), are generally derived from empirical models (Conti et al. 2005; Toy et al. 2007; Shitzer and Tikuisis 2012), which may lead to errors in the evaluation results. However, several studies have evaluated Chinese regional characteristics and have estimated the thermal comfort of the tourism climate by using advanced thermal indexes based on the human energy balance. Based on the PET and thermal comfort classifications in temperate and sub-tropical regions, Lin and Matzarakis (2011) have indicated that individuals residing in temperate regions perceive Taiwan Island and Eastern China as comfortable during the spring and autumn and that individuals residing in sub-tropical regions perceive the southern and northern regions as comfortable during the spring and summer, respectively. Li and Chi (2014) have evaluated thermal comfort and its changes in the Qinghai-Tibet Plateau over the last 50 years by using the PET, and a more complete picture of the tourism climate condition is been presented by the CTIS. However, because of China's vast land area, abundant resources and rapid tourism development, many areas of tourism climate research have not been explored in detail, especially in the wide regions of northwest China.

The Hexi Corridor (short name of the corridor west of the Huanghe River) is located in Gansu Province in northwest China and is composed of a series of alluvial plains that are formed by inland rivers between the Qilian Mountains (margin ranges of the Qinghai-Tibet Plateau) and Gobi Desert (Luo et al. 2014). This region has served as an important junction between the eastern and western regions of China since ancient times and plays an important role in the ancient Silk Road that links the Tianshan Corridor in central Asia with the initial section from Chang'an/Luoyang (Zhou et al. 2012). In 2013, to improve common development and prosperity, China has proposed to build the Silk Road economic belt to better connect Asian and European markets, which would reinvigorate the Silk Road and benefit all of the communities located along the Silk Road economic belt. With the establishment of "One Belt and One Road", there have been new opportunities for the development of tourism in the Hexi Corridor. Scenic attractions such as the Mogao Grottoes in Dunhuang and the Danxia landform in Zhangye have attracted several domestic and foreign visitors every year. Thus, studies regarding the bioclimatic conditions of this region should be conducted.

The objectives of this study include the following: (1) to generalise the thermal index (PET) based on the human energy balance when evaluating the bioclimatic conditions of China and (2) to provide additional details regarding the impact of climate on tourism activities in the Hexi Corridor. This paper is structured as follows. Section 2 presents an overview of the research area and the PET and CTIS. Section 3 provides research results from spatial and temporal perspectives. Section 4 presents the discussion and conclusion.

2 Data and methods

2.1 Study area

The Hexi Corridor is located in the western portion of northwest China's Gansu Province, which currently includes the five prefecture-level cities of Jiayuguan, Jiuquan, Zhangye, Jinchang and Wuwei from west to east, respectively (Fig. 1), in which the famous county-level city of Dunhuang is located in Jiuquan. The climate in this region is the arid continental climate of the Asian inland. Marine moisture is rarely transported to this area because it is located far from the ocean and the mountainous Qinghai-Tibet Plateau serves as a barrier. Because of the continental climate and topography, the mean annual temperature increases from southeast to northwest and the precipitation decreases from southeast to northwest. The daily and annual temperature ranges are large, and most of the rainy days and precipitation occur during summer (Meng et al. 2013). Because the Hexi Corridor is located in an arid and semi-arid region with scarce precipitation, intensive evaporation, water shortages and extreme fragility, it is extremely sensitive to climate change (Liu 2003).

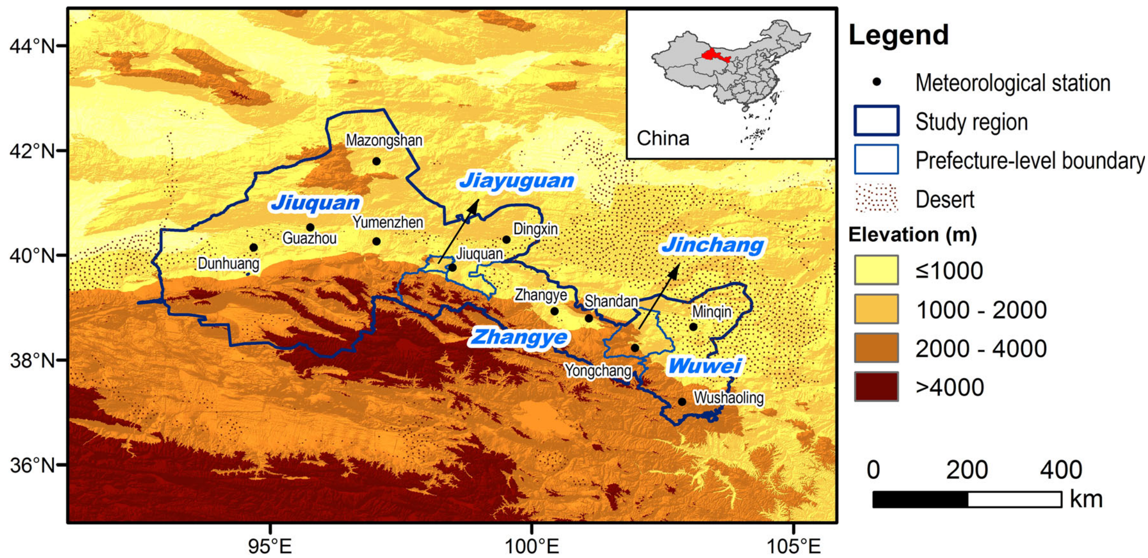


Fig. 1 Administrative division and spatial distribution of the meteorological stations in the Hexi Corridor in Gansu Province, China

2.2 Physiologically equivalent temperature

According to the human energy balance theory, the PET at any given location, including outdoor and indoor locations (Mayer and Höppe 1987; Höppe 1999; Matzarakis et al. 1999), is equivalent to the indoor air temperature that is required to reproduce in a standardised indoor setting and for a standardised person the core and skin temperatures that are observed under the conditions being assessed. The standardised person has a work metabolism of 80 W during light activity (in addition to basic metabolism) and 0.9 Clo of clothing-related heat resistance (Matzarakis and Mayer 1997; Matzarakis and Amelung 2008).

The PET approach is used to evaluate the thermal environment and thermal comfort human based on physiologically significant responses. The common unit "degrees Celsius" is used as an indicator of thermal comfort, which allows tourists, planners and policy makers who may not be familiar with human-biometeorological terminology to easily understand and comprehend the results (Matzarakis et al. 1999). The PET is calculated using the RayMan model for individual meteorological stations, and the following meteorological variables must be input: air temperature, vapour pressure, relative humidity, wind velocity and cloud cover (Matzarakis et al. 2007, 2010).

According to Matzarakis and Mayer (1996), who define the thermal comfort strain classes for central Europe, the PET index uses a nine-point thermal sensation scale. Lin and Matzarakis (2011) have performed a comparative analysis of human thermal perception classifications between temperate regions (central Europe) and sub-tropical (Taiwan) regions. Because of the latitude of the Hexi Corridor, the thermal sensation scale of central Europe is selected to use in this study (Table 1).

Table 1 The PET (°C) ranges for different grades of human thermal perception between central Europe and Taiwan

PET (°C) in central Europe	PET (°C) in Taiwan	Thermal perception	Grades of physiological stress
≤4	≤14	Very cold	Extreme cold stress
4–8	14–18	Cold	Strong cold stress
8–13	18–22	Cool	Moderate cold stress
13–18	22–26	Slightly cool	Slight cold stress
18–23	26–30	Comfortable	No thermal stress
23–29	30–34	Slightly warm	Slight hot stress
29–35	34–38	Warm	Moderate hot stress
35–41	38–42	Hot	Strong hot stress
>41	>42	Very hot	Extreme hot stress

Source: Matzarakis and Mayer (1996) and Lin and Matzarakis (2008)

2.3 Climate-tourism/transfer-information-scheme

Based on climate thresholds, the CTIS is projected to integrate and simplify climate information for tourism (Lin and Matzarakis 2008; Zaninovic and Matzarakis 2009). All factors, such as thermal comfort (hot stress, cold stress and thermal comfort), aesthetic (sunshine and fog) and physical components (windy, rainy, dry and sultry), are included in one single information scheme to provide a high temporal resolution description of these factors. Specifically, the selected factors and criteria for the thermal component include hot stress (PET >35 °C), cold stress (PET <0 °C) and thermal comfort (18 °C < PET < 29 °C). To account for aesthetic aspects, the factors visibility and sunshine (cloud cover <5 octas) and fog (relative humidity >93 %) are included. In addition, the physical factors of windy (wind velocity >8 m/s), rainy (precipitation >5 mm), dry (precipitation <1 mm) and sultry (vapour pressure >18 hPa) days are considered (Matzarakis 2013).

For tourism, the CTIS can provide all of the seasonal frequency classes and extreme weather event frequencies on a 10-day or monthly timescale. A 10-day temporal resolution is considered appropriate, as this time span is very close to the mean vacation duration (Zaninovic and Matzarakis 2009; Matzarakis 2013). After analysing the data from the climate stations or grid points, the included factors and parameters are revealed in terms of thresholds and frequencies. Furthermore, the frequencies can be sorted into qualitative classes. The probability CTIS scale is expressed in seven climate classes that range from "very poor" to "ideal", with a probability of approximately 14 % for each class (Table 2). For the hot stress, cold stress, foggy, windy, rainy and sultry day parameters, a greater probability indicates less favourable conditions; however, for the parameters of thermal comfort, sunshine and dry days, a greater probability indicates more favourable conditions (Matzarakis 2013, 2014).

Table 2 Description of the range for CTIS rating, in which colour range describes percent

Color	Range of percent values (%)	Description
	<14	unfavorable
	14-28	↕
	28-42	
	42-56	moderate
	56-70	↕
	70-84	
	>84	ideal

Source: Zaninovic and Matzarakis (2009) and Matzarakis (2014)

2.4 Data processing

In the Hexi Corridor, according to the continuity and maximum limitation periods of the meteorological data, 11 meteorological stations are selected (Fig. 1, Table 3). The daily mean data on air temperature, relative humidity, vapour pressure, wind velocity, cloud cover and precipitation (total daily amount) are obtained from January 1, 1980, to February 31, 2012, and all of the daily meteorological data used to represent the mean daily climate conditions are available from the China Meteorological Data Sharing Service System (http://data.cma.cn/).

The meteorological wind velocity data are obtained at a height of 10 m above the ground; however, because 1.1 m represents the weight centre of the human body, the data must be converted from 10 to 1.1 m (Matzarakis et al. 2009). Several empirical formulas are used to calculate the height dependency of wind velocity. The most widely applied formula is as follows:

$V = V_i\,(H / H_i)^n$,

where V (m/s) and V_i (m/s) are the wind velocities at the heights of H and H_i, respectively, and n is a correlation coefficient, which is 0.2 in the Hexi Corridor (Liu 1983; Lai et al. 2014).

3 Results and analyses

3.1 Summary of regional tourism climate information

From 1980 to 2012, the daily PET values in the Hexi Corridor covered eight sensation scales, excluding the perception of very hot (Fig. 2). The mean PET value within the examined period was 5.6 °C; the absolute maximum PET value was 37.8 °C, and the absolute minimum PET value was −33.0 °C. Cold or cool stress prevailed throughout the 33

Table 3 Meteorological stations in the Hexi Corridor

Station	Latitude (° N)	Longitude (° E)	Elevation (m)
Wushaoling	37.20	102.87	3045
Yongchang	38.23	101.97	1977
Minqin	38.63	103.08	1368
Shandan	38.80	101.08	1765
Zhangye	38.93	100.43	1483
Jiuquan	39.77	98.48	1477
Dunhuang	40.15	94.68	1139
Yumenzhen	40.27	97.03	1526
Dingxin	40.30	99.52	1177
Guazhou	40.53	95.77	1171
Mazongshan	41.80	97.03	1770

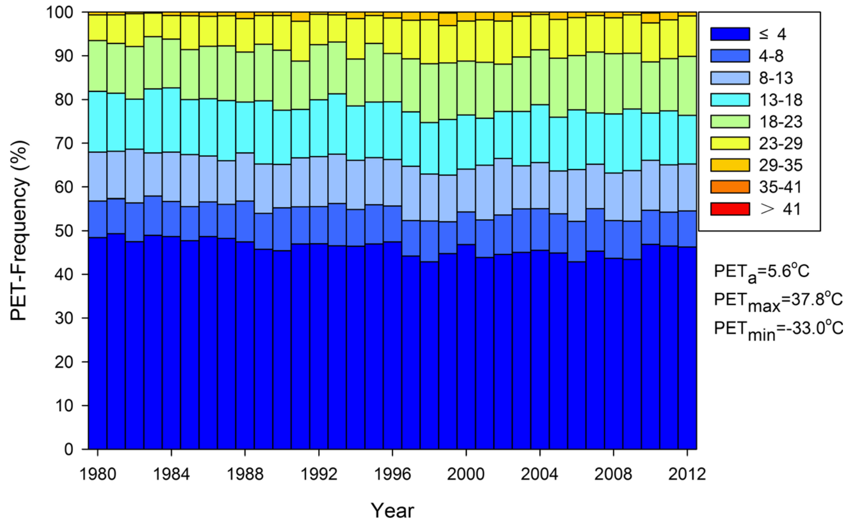


Fig. 2 Annual frequency of PET classes in the Hexi Corridor from 1980 to 2012

studied years (approximately 65.8 %), with warm or hot stress reported on approximately 1.2 % of the days and comfortable conditions reported on approximately 33.0 % of the days.

To determine the average daily PET values in the Hexi Corridor each year, the average daily PET values at the 11 meteorological stations were calculated from 1980 to 2012. To provide more comprehensive and useful climate information for the area, the average PET values were calculated for three types of intervals: 1-day, 10-day and 1-month intervals. According to the thermal perception classifications, if the PET value was between 13 and 29 °C (Table 1), the climate conditions in the area were comfortable or neutral. The results indicated that comfortable days began on the 16th of May and end on the 23rd of September, which was equivalent to the 14th 10-day period (mid-May) to the 26th 10-day period (mid-September) of the year. Therefore, May, June, July, August and September were the neutral months (Fig. 3).

The annual average cumulative numbers of days classified using the eight-point sensation scale from very cold to hot were 168.6, 31.5, 40.0, 46.4, 44.7, 29.3, 4.4 and 0.1, and the numbers of mean cold, comfortable and hot days were 240.1, 120.4 and 4.5, respectively. Considering changes in the mean cold, comfortable and hot days over the last 33 years, linear regression analysis results were presented and revealed that the regression coefficients of the above-mentioned three types of days were −0.447, 0.341 and 0.106, respectively (Fig. 4). The results indicated that the annual cumulative numbers of relatively cold days decreased and that the numbers of comfortable and relatively hot days increased.

In the 33 evaluated years, most neutral and slightly warm/cool days (greater than 42 %) occurred during the summer months from May to September, especially during the mid to late of June, July and September, which exhibited the highest percentages of neutral and slightly warm/cool days

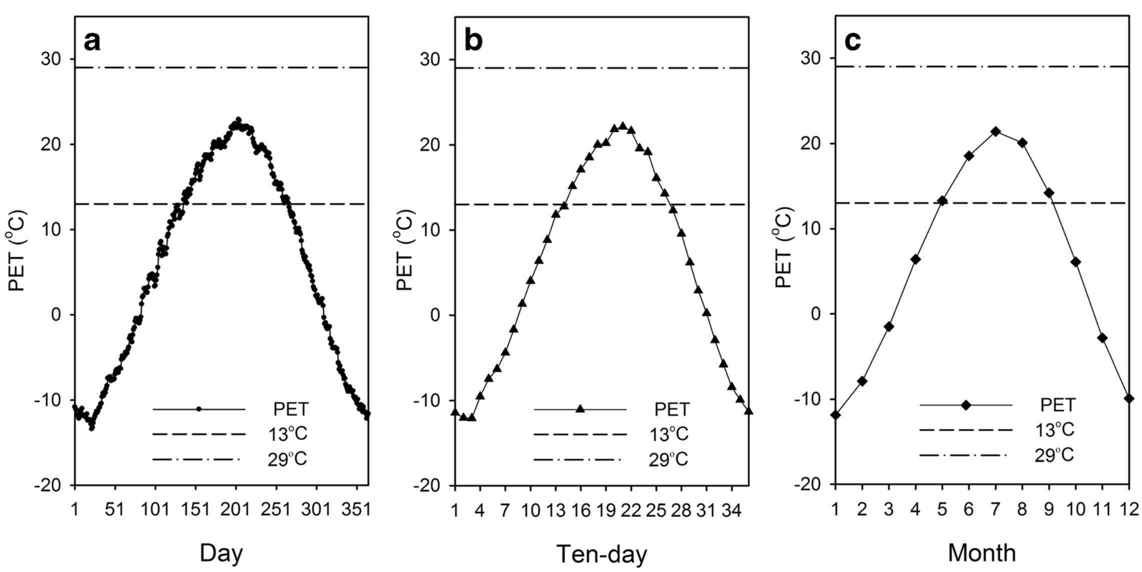


Fig. 3 Annual variance of the PET at different scales in the Hexi Corridor from 1980 to 2012

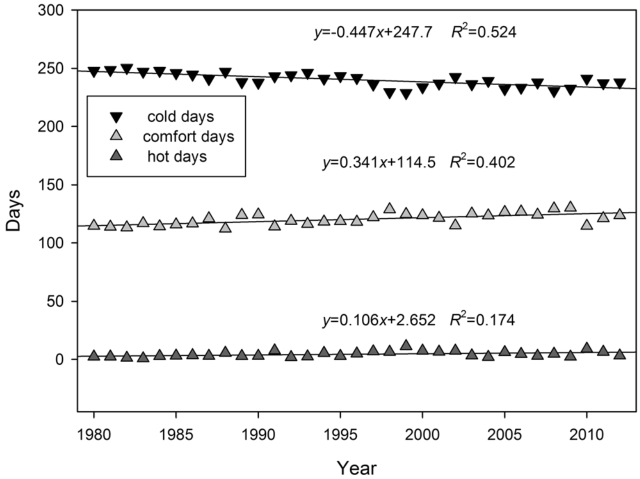


Fig. 4 Annual variations in warm and cool days in the Hexi Corridor from 1980 to 2012

(greater than 80 %). Therefore, summer was relatively favourable for most outdoor tourism and recreational activities. However, cold or cool stresses were dominant during the winter months from October to April next year, with an occurrence rate of more than 90 % from the mid-October to the early April next year. In addition, this rate could reach 100 % in November, December and January (Fig. 5). This conclusion was consistent with the prophase calculations on the first and last average comfortable days.

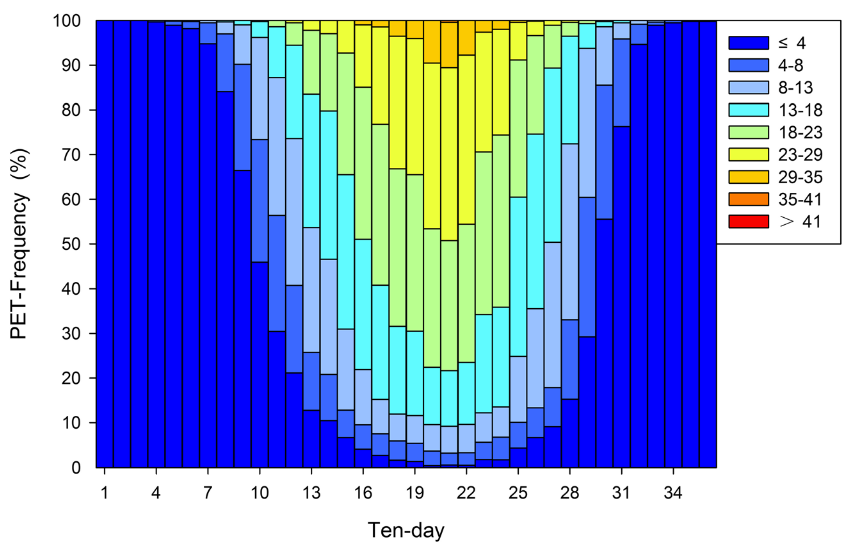
3.2 Contrast analysis of two meteorological stations

Dunhuang is located at the junction of Gansu, Qinghai and Xinjiang provinces in northwest China, and it is the most western city of the Hexi Corridor, which is famous for its extensive and profound cultural attractions, such as the Mogao Grottoes. Located at the southeast end of the Qilian Mountains, the Wushao Range is the natural boundary between the Loess Plateau and the Hexi Corridor and is the dividing line between the semi-arid and arid zones and marks the western end of the East Asian monsoon region. Dunhuang and Wushaoling are both choke points of the Silk Road, and Wushaoling is the highest meteorological station in the Hexi Corridor. The bioclimatic and tourism climate information from the two meteorological stations is considered typical and representative. Analysing the climate information of the two stations in more detail will improve the understanding of the variance in the tourism climate potential of the Hexi Corridor.

In Dunhuang, hot and very hot conditions did not occur, and warm conditions only occurred for an average of 19 days. Very cold conditions were common in November, December, January, February and March (more than 130 days). The numbers of cold and cool days were only 38 and 36, respectively. Thus, suitable days were 152 from mid-April to the early October, with more than 42 % suitable days during this period and with more than 80 % suitable days from May to September. Specifically, the PET value ranging 18 to 23 °C began in April and ends in October, with a relatively large frequency occurring in May, June and September and the maximum value (49 %) occurring in May (Fig. 6). The results demonstrated that the most optimal period for tourism and tourist activities was from May to September.

Wushaoling has a cold climate because it is located at a high altitude. The daily PET values at Wushaoling only included the following four points of the nine-point sensation scale: very cold, cold, cool and slightly cool (corresponding with mean days of 268, 55, 37 and 4, respectively). From November to the early April next year, the area was dominated by very cold stress. During the remainder of April and October, more than 90 % of the days were very cold. Cold or cool conditions were common from May to September, with a frequency of 20 and 85 %, respectively. Conversely,

Fig. 5 Frequency of PET classes in the Hexi Corridor from 1980 to 2012



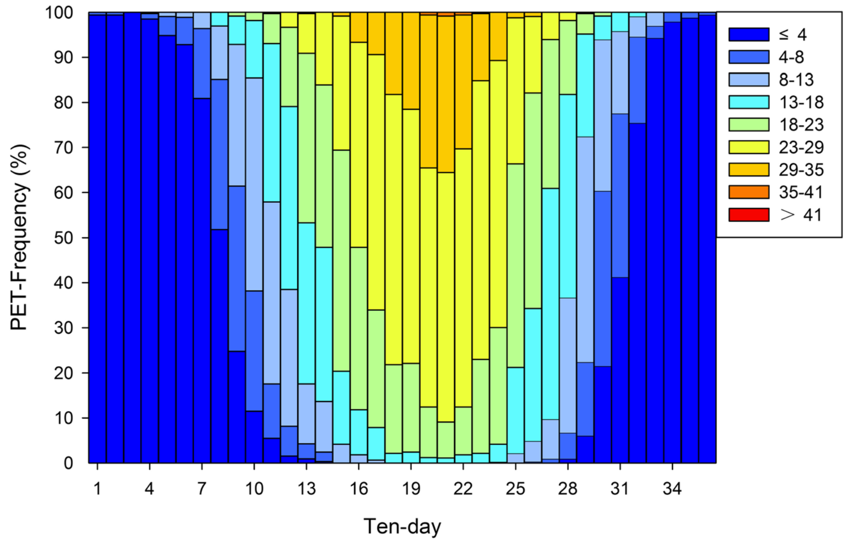


Fig. 6 Frequency of the PET classes in Dunhuang from 1980 to 2012

slightly cool conditions were relatively rare and present maximum frequencies (10 %) from the mid to late of July to the early August (Fig. 7).

The annual variations in different parameters related to tourism and recreation are summarised in the CTIS. The two stations are selected because Wushaoling is the only mountain observatory and Dunhuang is a world-famous tourism area, in which Dunhuang is similar in geographic location to the remaining meteorological stations. In addition to providing thermal comfort information, the CTIS can present other requisite parameters for tourism planning and management, such as aesthetic and physical components (Fig. 8). The CTIS rating for Dunhuang indicated that the area was ideal in terms of hot stress, foggy, windy, rainy, dry and sultry throughout the year, and the numbers of days with sunshine were consistently greater than 40 %. According to the PET frequency (Fig. 6), the thermally comfortable conditions tended to occur less often in Dunhuang. Generally, Dunhuang presented favourable conditions in terms of tourism climate from May to September. In contrast, cold stress was experienced throughout the region of Wushaoling with infrequent thermally comfortable conditions throughout the year.

3.3 Variations among the regions over the travel periods

The aforementioned analysis indicated that the optimal travel period for the Hexi Corridor was from May to September. To evaluate regional differences in the tourism climate of this area, the monthly average PET values for a number of years and their changes from 1980 to 2012 were calculated at the 11 meteorological stations and were presented in this paper.

In Wushaoling, the average PET values during the travel period (May to September) were all less than 13 °C and cool or cold thermal conditions were dominant. The average PET

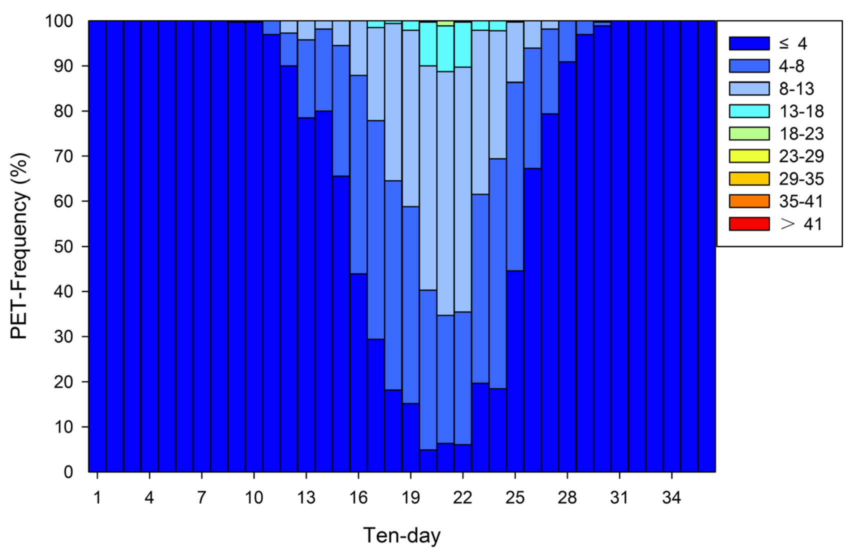


Fig. 7 Frequency of the PET classes in Wushaoling from 1980 to 2012

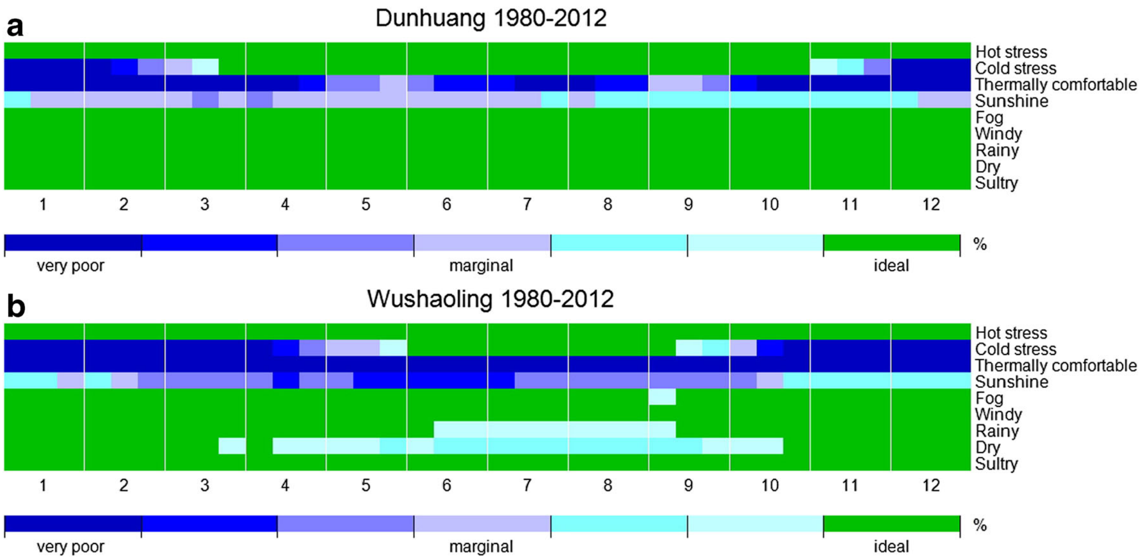


Fig. 8 CTIS on a 10-day timescale for Dunhuang (**a**) and Wushaoling (**b**) from 1980 to 2012

values at the remaining stations were all between 13 and 29 °C during the summer months (June, July and August) except at Wushaoling. At Mazongshan and Jinchang, the average PET values during the first and last 2 months of the travel period were below 13 °C. In Shandan, the average PET value was 12.8 °C in May, which was close to 13 °C. Generally, the

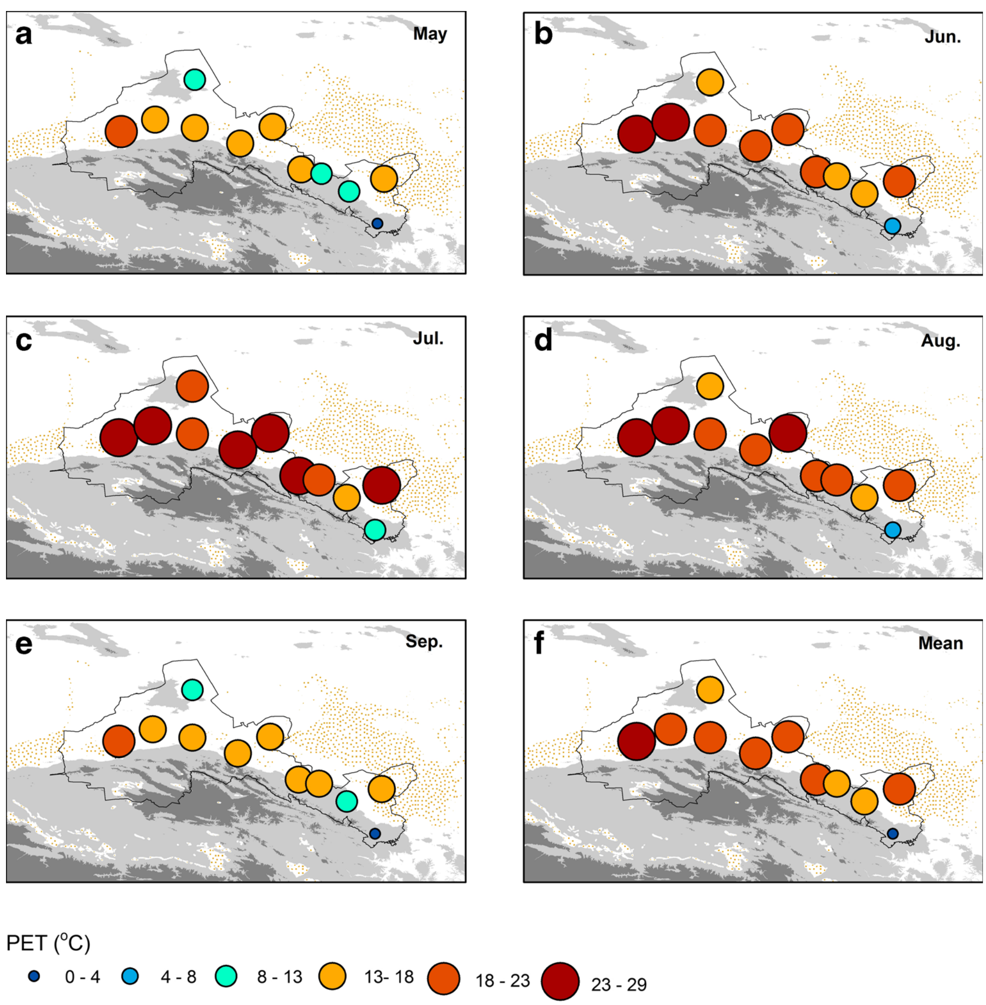


Fig. 9 Monthly mean PET values in the Hexi Corridor during the optimal travel period from 1980 to 2012. *White shading* denotes altitudes of less than 2000 m, and *dark grey shadows* indicate altitudes greater than 4000 m. The altitude of the *lighter grey area* is between 2000 and 4000 m, and the *small dots* indicate desert regions

thermal conditions in the Hexi Corridor were suitable for conducting tourism activities during the travel period (Fig. 9). However, the results for Wushaoling and Jinchang indicated that they were much cooler than the other regions as a result of their higher altitude in the Hexi Corridor. In addition, the results for Mazongshan indicated that it was only suitable for tourism during the summer because of its high latitude. Furthermore, the other stations present generally favourable climate conditions for tourism during the travel period.

In May, June, July and August, the monthly mean PET values of the 11 meteorological stations linearly increased from 1980 to 2012. In September, the monthly mean PET values of Dingxin and Minqin linearly decreased during 1980–2012 (Fig. 10), and the monthly mean PET values of the rest meteorological stations linearly increased during this period. Thus, in the setting of global warming, the optimal travel period will occur earlier and sustain over a longer period than previous recorded. These conditions are beneficial for travelling in the Hexi Corridor, which is dominated by cold stress.

4 Discussion and conclusion

In this paper, the tourism climate conditions for the Hexi Corridor are discussed, and the results presented in this paper represent a preliminary analysis of the local tourism conditions. This paper is an attempt to estimate the tourism climate of northwest China using a thermal index (PET) based on the human energy balance, and geographic information systems (GIS) are applied to study the regional differentiation as several previous researches. First, the advanced PET and CTIS approaches were used to analyse the spatial and temporal distribution characteristics of the tourism climate conditions in the Hexi Corridor. Second, the data from the Wushaoling and Dunhuang meteorological stations located on the east and west sides of the Hexi Corridor were compared to determine

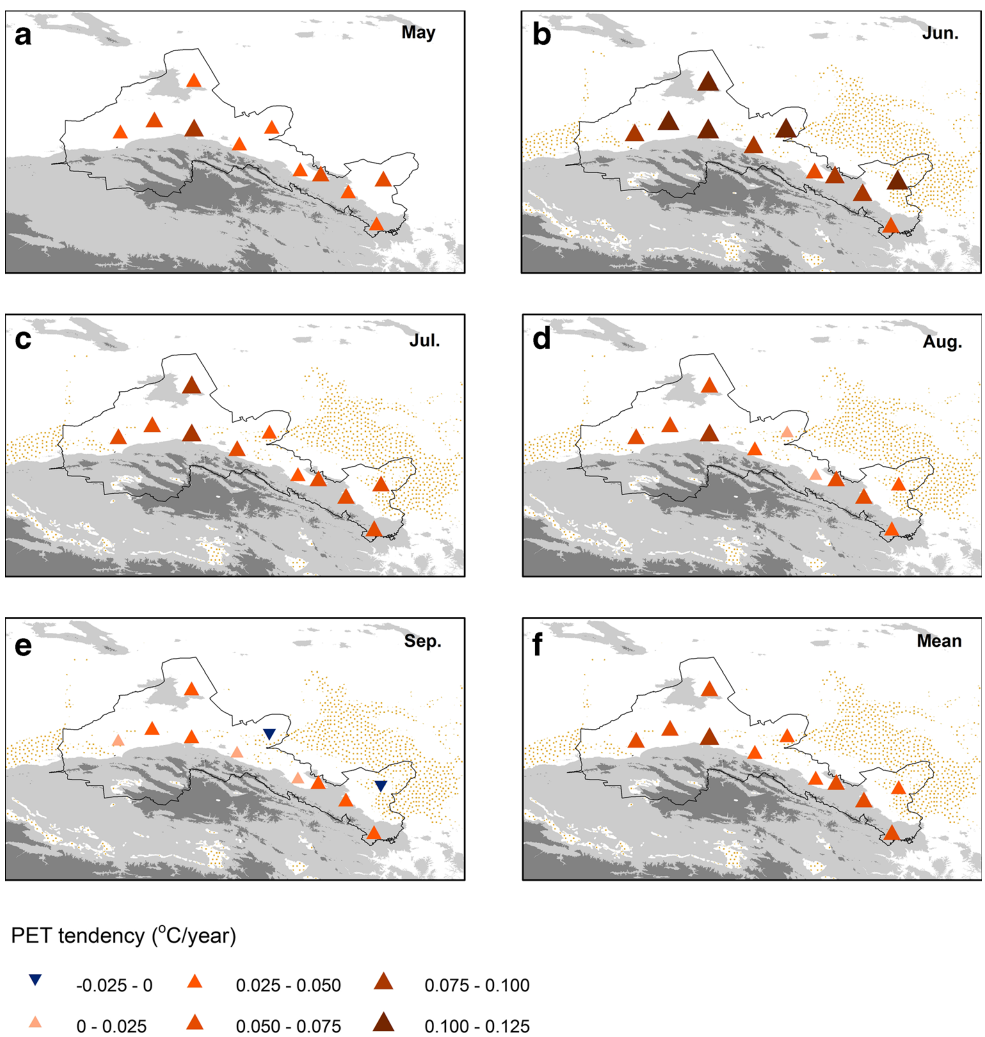


Fig. 10 Interannual variability of the monthly mean PET in the Hexi Corridor during the optimal travel period from 1980 to 2012. *White shading* denotes altitudes of less than 2000 m, and *dark grey shadows* indicate altitudes of more than 4000 m. The altitudes of the *grey area* are between 2000 and 4000 m, and the *small dots* indicate desert areas

the frequencies of PET and CTIS. The information from these areas indicated that the conditions were beneficial for the tourism industry. Finally, May, June, July, August and September were identified as the neutral months for tourism activities, and the PET values and the average linear tendencies of these 5 months were determined. The results demonstrated that regional variations in the tourism climate conditions are influenced by differences in latitude and elevation and that most areas in the Hexi Corridor were suitable for tourism activities during the optimal travel period.

This is the first case study regarding the tourism climate conditions in northwest China that has applied a complex thermal index (PET) based on the human energy balance. Pu and Yao (2010) and Jia and Lu (2010) have applied traditional indexes based on a statistical model, including the temperature-humidity index (THI), wind chill index (WCI) and index of clothing (ICL), to estimate the degree of human comfort or the human habit climate comfort in Gansu Province. Their results indicated that the human comfort ranged from cool to comfortable, with the cool days occurring over 60 % of the year. The human comfortable days were nearly 6 months in most places of Gansu Province such as the Hexi area. Overall, the climate conditions in Hexi Corridor were more comfortable during the summer. Comparing their studies of climate conditions in this region, the results found in our study were quite similar and more accurate regarding thermal comfort. When calculating the daily PET values from 1980 to 2012, cold or cool stress was dominant in the area, with a frequency of 65.8 %. The optimal travel period lasted from May to September or from the 14th to the 26th 10-day period of the year, which was from May 16 to September 23. In addition, with global warming, the annual cumulative numbers of days with relatively cold conditions decreased and the annual cumulative numbers of days with comfortable and relatively hot conditions increased. As mentioned in the Sect. 1, Li and Chi (2014) have calculated the PET of the Qinghai-Tibet Plateau and indicated that the annual cumulative numbers of thermally favourable days were increasing, and the numbers of days associated with cold stress were decreasing. Similar locations are analysed between the Qinghai-Tibet Plateau and the Hexi Corridor in this study, and similar results are observed and similar conclusions are reached. Therefore, the indexes based on human energy are universally applicable and may be used more general.

However, the specific meteorological data used to evaluate bioclimatic conditions are relatively rare in so large areas; therefore, meteorological data derived from meteorological departments at various levels must be adopted. In addition, tourist activity frequently occurs during daytime hours; therefore, the 14 h of daylight data is often used to estimate the tourism climate conditions, but these data are generally unavailable at present. Northwest China presents a larger range of daily temperatures; therefore, the research results based on the mean daily data may present certain limitations. The reanalysis data released from the National Centres for Environmental Prediction and the European Centre for Medium-Range Weather consist of globally gridded climate data for historical climate conditions (Grotjahn 2008). These data can be used to fill in missing data resulting from a lack of meteorological datasets and can supply additional details regarding the climatological factors used to estimate bioclimatic conditions. A comparison of the meteorological climate databases and gridded datasets will improve the accuracy of the results in the related research. In addition, the effects of climate change and potential changes in the tourism climate are significant for tourism. To reveal and assess the effects of potential change on bioclimatic conditions, regional climate models (RCM) that are capable of generating climate simulations and predictions are often used (Shiue and Matzarakis 2011; Endler and Matzarakis 2011; Brosy et al. 2014), which extend the field of tourism climate research.

In general, the numbers of meteorological stations considered in this study are limited, and the time sequence for the meteorological stations is short, so the accuracy of the results may not be optimal. A follow-up study should be performed to combine measured data with reanalysis data, and this result indicates that conducting specific meteorological monitoring is indispensable for future research. Furthermore, the thermal comfort classification using the European scale is applied to the PET frequencies in this research, and the scale should be adjusted for to local thermal comfort classifications. Likewise, The CTIS also should fit the new thresholds to local environmental conditions and tourist activities and add or remove related tourism climate parameters according to the actual situation. Although the current results have limitations, they provide novel insights into the tourism climate conditions in the investigated region. The researches regarding the effects of climate on tourism in the Hexi Corridor are useful for different aspects of tourism, including travel agencies, resorts and tourists. Thus, this research should be used to promote the development of the tourism industry in the region.

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