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An Assessment of Tourism Climate Comfort in the China–Pakistan Economic Corridor

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Abstract: Pleasant climates can be divided into two types: the comfortable summer climate and the comfortable winter climate, but existing studies rarely pay attention to the distribution characteristics and differences between the two types of climate. This study investigates the spatial distribution of comfortable summer and winter climates in the China–Pakistan Economic Corridor (CPEC) and their differences based on the European Centre for Medium-Range Weather Forecasts Re-Analysis-Interim (ERA-interim) reanalysis data from 1979 to 2018. The Universal Thermal Climate Index was used to analyze climatic suitability. The findings are as follows. First, the comfortable summer climate regions of the CPEC were mainly distributed in Khyber Pakhtunkhwa in Pakistan and some regions of Xinjiang in China and also sporadically distributed in high altitude mountains, such as the western plateau area. The comfortable winter climate regions were mainly distributed in vast areas except for Karakoram and nearby areas. Second, there are a few regions with dual attributes of comfortable summer and winter climates in CPEC. Third, according to the calculation and comparison of the regional area of different climate comfort levels in summer and winter, it is found that the comfortable summer climate is scarcer in CPEC and is a monopoly resource. The comfortable winter climate is widely distributed, belonging to the ubiquitous resources. These findings can be helpful for the tourism development of local climate resources.

Keywords: thermal comfort; tourism; universal thermal climate index; CPEC

1. Introduction

Tourism, which is one of the largest industries in the world, has the most powerful developmental momentum. The development of tourism is deeply affected by climate [1], leading to significant challenges and potential paradoxes in governance and long-term development [2]. Adaptation to climate is the premise of promoting sustainable tourism development. Nationwide tourism climate information will be helpful for the optimization of the tourism industry and the development of tourism destinations [3]. Thermal indices are a basic index to measure whether the thermal condition of the region is suitable for tourism activities.

Since the 20th century, more than 100 thermal indices have been developed to define thermal comfort in the world [4,5]. Among these indices, several indices have been calculated and proposed to

assess the suitability of the climate for tourism activities [1,2,6–11]. The Climate Index for Tourism (CIT) proposed by Mieczkowski is the most widely known and applied index to evaluate the tourism thermal environment [12]. However, the CIT does not consider human thermo-physiology, human comfort, and discomfort, which are important factors for tourists and their satisfaction during a holiday [13]. Besides this, there is a critical limitation of the CIT in that it is as an 'expert-based' index. The meaning attached to the index was secondarily derived from the biometeorology literature and Mieczkowski's subjective opinion [9]. Therefore, several methods were designed and proposed for calculating thermal comfort based on human biometeorology. More specifically, one such index is the Universal Thermal Climate Index (UTCI), applied in many countries, regions or localities to assess human thermal comfort. Some studies found that UTCI was sensitive to slight changes in climatic variables and was suitable for thermal assessments in all climates and seasons, and on any scale [14,15]. Additionally, UTCI depicted the temporal variability of thermal conditions better than other indices [16].

Pleasant climate refers to climate conditions that the human body feels comfortable in without the help of hot and cold prevention facilities. It can be divided into two types: the comfortable summer climate and the comfortable winter climate. Many studies have used various thermal indices to evaluate thermal conditions for tourism. Fang and Yin [17] through seasonal distribution maps of CIT scores found that the climates of most regions in China are comfortable for tourists during spring and autumn, while the climate conditions differ greatly in summer and winter, with "excellent", "good", "acceptable" and "unfavorable" existing almost by a latitudinal gradation. Morgan et al. [6] made the link between user-generated ratings for various climatic conditions and published climate data, developed the Beach Comfort Index (BCI), and evaluated the most major Euro-Mediterranean/Black Sea and a range of other beach tourism areas on a month-by-month basis. Similar thermal comfort assessments for tourism have been studied in Hungary [18], Algeria [19], Croatia [20], Iran [21], etc. Until now, according to the research on the pleasant climate of the China–Pakistan Economic Corridor (CPEC), there are only some studies on indoor thermal comfort and urban outdoor heat exposure [22,23]. In a previous study [24], we studied the overall distribution characteristics of UTCI in this region. However, the research is relatively rough, and there is no special research on tourism. In recent years, the number of tourists in the China–Pakistan Economic Corridor (CPEC) has increased significantly. For example, 1.6 million and 6.6 million tourists were received across Pakistan in 2014 and in 2018, respectively, with a total increase of 317% over five years. Therefore, it is necessary to meet the needs of the rapid development of tourism in the CPEC and carry out large regional-scale tourism climate research.

To summarize, the CIT does not consider human thermal physiology and human comfort. Moreover, it is subjective to a certain extent. Thus, even if it is the mainstream method of tourism climate comfort evaluation, the UTCI, with its stronger applicability, is adopted in this study to meet the needs of the large research areas, complex climatic conditions, and multiple research seasons. In addition, the research objects of the relevant literature of the study area are mostly focused on a very small scale, mainly for indoor thermal comfort and urban outdoor heat exposure evaluation, with less research on a regional scale. There are also a few pieces of literature that compare the distribution characteristics and differences between the comfortable climate types in summer and winter. A comparison of these two types of climates is helpful to understand the distribution of climate resources in the study area and it is of great significance to guide the development of tourism-related industries in reality.

Therefore, this study is based on the ERA-interim reanalysis data from 1979 to 2018 for 40 years, combined with the UTCI model to investigate the spatial distribution of comfortable summer and winter climates in CPEC and their differences.

The remaining sections are organized as follows: Section 2 highlights the characterization of the study area, data, and methodology, while the results are given in Section 3. Finally, a discussion and the conclusion are presented in Sections 4 and 5, respectively.

2. Materials and Methods

2.1. Study Area

The China–Pakistan Economic Corridor (CPEC) covers an area of 1.05 million km^2, with mountainous areas accounting for about half of the territory (Figure 1). It is composed of China's Kashgar region and Pakistan, with more than 212 million inhabitants. The Kashgar region in China has a warm temperate continental climate, with hot summers but short hot summer periods, no severe winters, but long low-temperature periods. Pakistan has a tropical climate with generally high temperatures and sparse precipitation. Areas with annual precipitation less than 250 mm account for more than three quarters of the country's total area. The rest has a subtropical climate. The southern part is hot and humid, affected by monsoons, and the rainy season is longer; the northern part is dry and cold, and some places have snow all year round. The average annual temperature is 27 °C. Because of the wide range of climatic conditions in CPEC [25], rich tourism resources have been created. In addition to the rich natural landscape such as the mountains, plateau lakes, deserts, oceans, etc., CPEC also has a rich cultural landscape. This cultural landscape includes Islamabad, Taxila, Peshawar, and other famous religious tourist attractions, including ancient city sites representing the brilliant Indus River civilization such as Mohenjo-Daro, an international metropolis with seaside resorts such as Karachi, and the South Region of Xinjiang, which is rich with ethnic customs. These tourism resources are attracting more and more attention from global tourists. Tourism in CPEC has extensive and favorable development prospects.

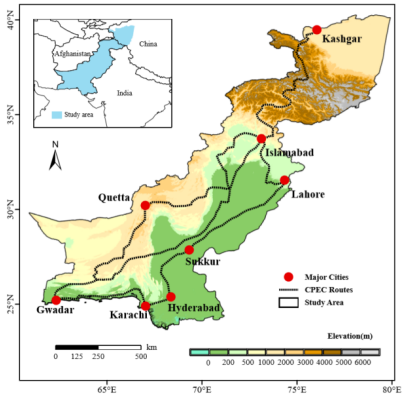


Figure 1. Topography and major cities of China–Pakistan Economic Corridor (CPEC).

2.2. Data

There are problems with insufficient numbers and the uneven distribution of meteorological stations. Grid data can solve these problems to a certain extent. Therefore, we plan to use ERA-interim reanalysis data as the basic data of the study. In our previous study, we confirmed the applicability of this data in this study area. The ERA-interim dataset [26] is the third-generation reanalysis dataset of the European Center for Medium-Range Weather Forecasts for the period since 1979. ERA-interim is considered an optimized version of ERA-15 and ERA-40. The moisture analysis, satellite data error correction, and other technologies were improved, and the latest four-dimensional variation data assimilation (4D-Var) was used, which has greatly improved the quality of the dataset.

We obtained 0.25° gridded daily ERA-interim reanalysis data during the period 1979–2018, including = 2-m air temperature(Ta, °C), 2-m dew-point temperature(Td, °C), 10-m V-component of wind (Vv, m/s), 10-m U-component of wind(Vu, m/s), and total cloud cover(N) at 11:00 and 17:00 Pakistan Standard Time (PKT) per day.

2.3. Methods

The UTCI provides a one-dimensional quantity reflecting the human physiological response to the multi-dimensional definition of actual thermal comfort [27,28]. It adopts a multi-node model of human thermoregulation and an adaptive clothing model to simulate human reaction [27]. UTCI is defined as the air temperature (Ta) of the reference condition, which causes the same model response as the actual condition [16,28]. These reference conditions include a person walking with a speed of 4 km/h (equivalent to a metabolic rate of 2.3 MET), a wind speed measured at a 10-m height following the meteorological convention of 0.5 m/s, a mean radiant temperature equaling air temperature, a relative humidity of 50% for Ta ≤ 29 °C, and a vapor pressure of 20 hPa for Ta > 29 °C [28]. The stress categories scale (Table 1) was developed on the basis of the simulated physiological and psychological response combined with the thermal physiological response of the human body [28].

Table 1. Universal Thermal Climate Index (UTCI) equivalent temperatures categorized in terms of thermal stress and thermal perception.

UTCI (°C)	Stress Category	Thermal Perception
>46	Extreme heat stress	Torrid
38–46	Very strong heat stress	Hottish
32–38	Strong heat stress	Hot
26–32	Moderate heat stress	Warm
9–26	No thermal stress	Comfortable
0–9	Slight cold stress	Cool
−13–0	Moderate cold stress	Coolish
−27–−13	Strong cold stress	Cold
−40–−27	Very strong cold stress	Chilly
<−40	Extreme cold stress	Freezing

It is computationally intensive and time-consuming to calculate UTCI by repeatedly running a temperature regulation model. For simple and fast computation, the UTCI calculation method based on the 6th order of UTCI approximated by a polynomial in 2-m air temperature (Ta), 10-m wind speed (V), vapor pressure (e), and mean radiant temperature (Tmrt) was employed [28].

$$\mathrm{UTCI} - Ta = \mathrm{f}\,(\mathrm{Ta},\ \mathrm{V},\ \mathrm{e},\ \mathrm{Tmrt}\ - \mathrm{Ta}) \tag{1}$$

The wind speed can be computed from the 10-m V-component of wind and 10-m U-component of wind:

$$\mathrm{V}\ = \sqrt{\mathrm{Vu}^2 + \mathrm{Vv}^2} \tag{2}$$

The vapor pressure is calculated from the dew point temperature [29]:

$$\mathrm{e}\ =\ 6.11\ \exp 5417.753\{(1\ /\ 273.16) - [1/(273.16 +\ \mathrm{Td})]\} \tag{3}$$

The formulation of the mean radiation temperature is as follows [30–33]:

$$\mathrm{Tmrt}\ = \left[(Rprim + 0.5Lg + 0.5La)/\left(0.95 \times 5.667 \times 10^{-8}\right)\right]^{1/4} - 273 \tag{4}$$

where *Rprim* is the solar radiation absorbed by a nude man and can be estimated by the SolAlt model, which has been proven reasonable by Douglas [34].

$$\mathrm{Lg}\ = 5.5 \times 10^{-8}(273 + Tg)^4 \tag{5}$$

$$\mathrm{La}\ = 5.5 \times 10^{-8}(273 + Ta)^4\left[0.82 - 0.25 \times 10^{(-0.094 \times 0.75e)}\right] \tag{6}$$

where Tg (°C) is surface temperature.

These calculation procedures are calculated by Bioklima2.6 software [35]. The UTCI was calculated at 11:00 and 17:00 PKT during the daytime. The daily UTCI was taken as the maximum of two values in the daytime. The estimation period was from 1 January 1979 to 31 December 2018.

The definition of comfortable summer climates and comfortable winter climates is the basis of this paper. The UTCI index is taken as the basic reference condition of climate types. According to the meteorological standard, the seasons are from June to August in summer and from December to February in winter. Based on the classification standard of thermal stress and thermal perception (see Table 1), a climate that is "cool" or "comfort" or "warm" is defined as pleasant climate, that is, $0 \leq$ UTCI in summer ≤ 32 is a comfortable summer climate, and $0 \leq$ UTCI in winter ≤ 32 is a comfortable winter climate.

3. Results

3.1. General Distribution Characteristics of UTCI in Summer

Figure 2 shows the spatial distribution of the UTCI in summer (June, July, August, and summer mean) of the CPEC. The results show that the distribution of a comfortable summer climate in CPEC is similar. The UTCI in the summer of the CPEC presents the regional distribution characteristics of two basic different regions in the north and the south. The UTCI in the north is generally lower than that in the south. In summer, the UTCI is mainly affected by latitude and terrain, and the areas with lower general thermal climate index have the characteristics of middle–high latitude or high altitude.

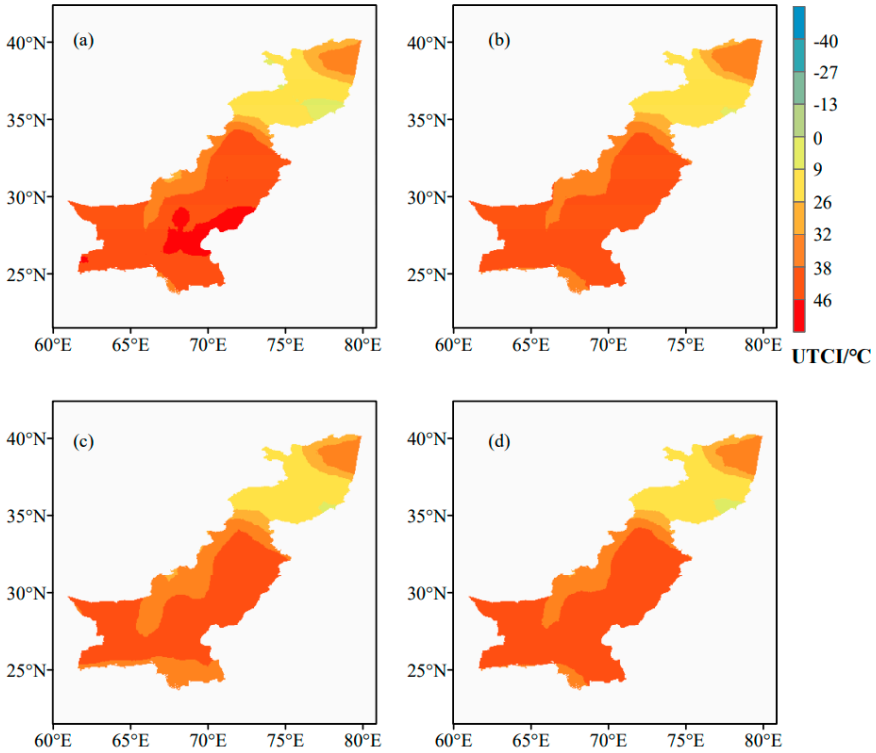


Figure 2. Spatial distribution of the UTCI during June (**a**), July (**b**), August (**c**), and summer (**d**) in CPEC.

Specifically, the comfortable summer climate of the CPEC is concentrated in the surrounding areas of Karakoram, mainly including Khyber Pakhtunkhwa in Pakistan and some regions of Xinjiang in China. In addition, the comfortable summer climate is also sporadically distributed in high altitude mountains, such as the western plateau area. Among them, a slightly lower elevation area near Karakoram is the most comfortable area in summer.

Relatively speaking, the spatial distribution range of less comfortable grades in summer is relatively large, mainly concentrated in northern Kashgar and the Indus River Plain. The average UTCI of these areas is above 32 degrees, involving Xinjiang, Sindh, Punjab, and Baluchistan. In addition, in June, the thermal stress level in southern Punjab, northern Sindh, and northeast Baluchistan is "extreme heat stress", and the thermal feeling is torrid. Generally speaking, the areas without a comfortable climate are widely distributed in summer, including Islamabad, Karachi, Lahore, and other economically developed and densely populated areas. There is a strong demand for tourism in the summer.

3.2. General Distribution Characteristics of UTCI in Winter

Figure 3 shows the spatial distribution of the UTCI in winter (December, January, February, and winter mean) in the CPEC. Based on the different months, the spatial distribution range of comfortable winter climate is the smallest in January (Figure 3b), and the area of the uncomfortable climate area is the largest, especially in Xinjiang. Compared with other months, the area of the uncomfortable climate in this region is obviously expanded. The climate distribution in December (Figure 3a) is basically consistent with that in winter (Figure 3d). In February (Figure 3c), the area of the comfortable winter climate was the largest, and "moderate heat stress" appeared in the southern coastal area.

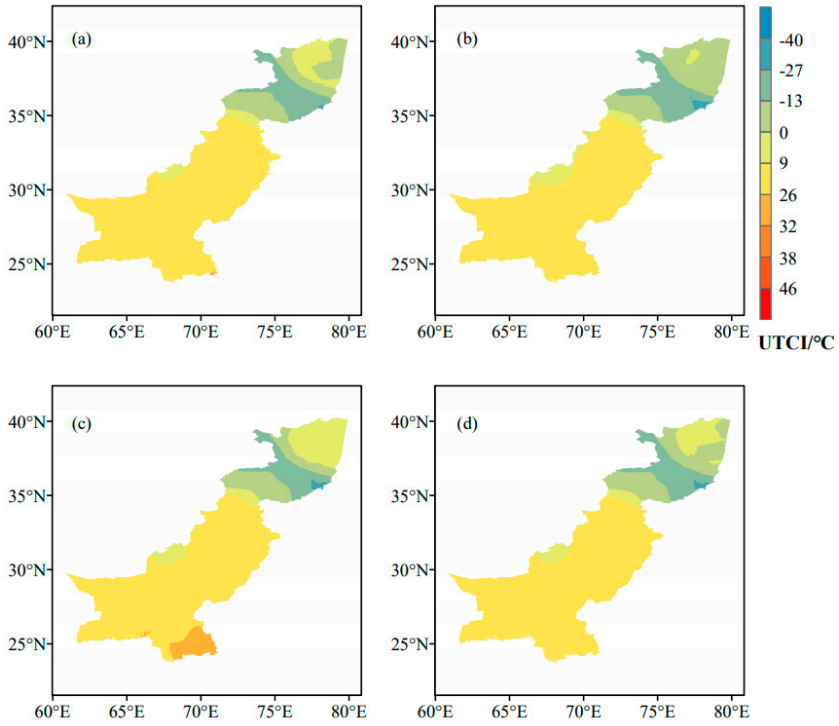


Figure 3. Spatial distribution of the UTCI during December (**a**), January (**b**), February (**c**), and winter (**d**) in CPEC.

As shown in Figure 3, the spatial distribution of UTCI during winter is obviously affected by altitude and latitude. The UTCI has a low value near the Karakorum. Xinjiang, in the north of the Karakorum Mountains, is affected by latitude. Compared with the vast areas in the south, the UTCI is also lower. In some parts of the western plateau, the UTCI is significantly lower than the surrounding areas.

The comfortable winter climate is mainly distributed in the vast areas except for Karakoram and nearby areas. The slight cold stress is mainly distributed in Xinjiang. The vast areas in the South including Sindh, Punjab, Baluchistan, and Khyber Pakhtunkhwa experience no thermal stress.

Generally speaking, the winter climate comfort degree of most areas in the CPEC is ideal. The comfort degree in the south of 35 °N is at the most comfortable level. The distribution areas that do not belong to the pleasant climate are mainly located near the Karakoram, where the altitude is relatively high, the population is relatively small and the economy is underdeveloped. Objectively speaking, there is little demand for cold shelter in the CPEC.

3.3. Differences in the Distribution of Summer Comfortable Climate and Winter Comfortable Climate

3.3.1. Distribution Characteristic of Different Types of Climate

Based on the UTCI of summer and winter, when the two UTCIs in summer and winter are both at the thermal feeling levels of "cool", "comfort" and "warm", i.e., 0–32, this is defined as a corresponding pleasant climate grid point. According to the climate attributes of comfortable summer and winter climates, the grids in CPEC are classified into four types: comfortable summer climate, comfortable winter climate, comfortable summer and winter climates, and unsuitable climate.

Combined with the number of different types of grid points (Table 2) and distribution characteristics (Figure 4), the grid points that belong to comfortable summer and winter climates in the CPEC are relatively small, mainly distributed in southern Karakoram and Xinjiang, and sporadically distributed in the western plateau. The number of comfortable winter climate grid points accounted for 73.39%, mainly distributed in the south at 35 °N. Relatively speaking, there are only 320 grid points for comfortable summer climate, reaching 19.99% of the total grid points, which are concentrated in the high altitude areas near Karakoram, Xinjiang and other high-latitude areas. The grid points of unsuitable climate types accounted for the smallest proportion of the four types, as low as 1.94%, and were mainly distributed in Xinjiang.

Table 2. Comparative analysis of grid points in regard to different types of climates.

Grid Type	Grid Number	Proportion (%)	Main Distribution Provinces
Summer	320	19.99	Xinjiang, Khyber Pakhtunkhwa
Winter	1175	73.39	All
Summer and Winter	75	4.68	Xinjiang, Khyber Pakhtunkhwa
Unsuitable	31	1.94	Xinjiang

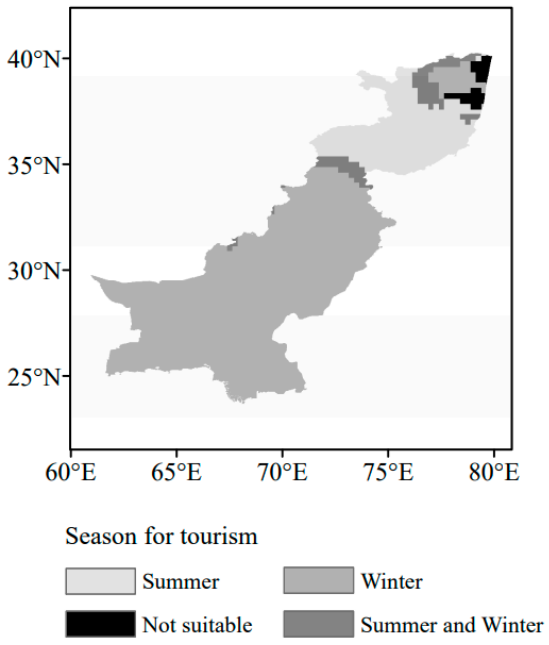


Figure 4. Spatial distribution of different types of climate in CPEC.

From the above analysis, it can be seen that the comfortable winter climate is widely distributed in the CPEC. However, the distribution of the comfortable summer climate is relatively concentrated, and the demand for summer vacations is more considerable than that for winter vacations. Therefore, the comfortable summer climate is a potential tourism resource. However, due to the spatial heterogeneity of the climate, there are few places with comfortable summer climates and comfortable winter climates. The two types of climates show obvious regional separation characteristics.

3.3.2. Area Comparison of Different Thermal Stress Levels in Summer and Winter

The distribution of thermal stress categories during summer and winter from 1979 to 2018 are shown in Table 3. According to the statistics of the monthly and monthly average area in the quarter, the area of comfortable summer climate accounts for 24.67% of the CPEC, and the comfort level is around 18.24%. At the same time, the regional area of uncomfortable areas accounted for 75.33%, while 56.78% were in the "very strong heat stress" category with a thermal perception of it feeling hot.

Table 3. Distribution of thermal stress categories by total area and percentage of the area during summer and winter from 1979 to 2018.

	Extreme Cold Stress		**Very Strong Cold Stress**		**Strong Cold Stress**		**Moderate Cold Stress**		**Slight Cold Stress**	
	Area	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**
June	0	0	0	0	0	0	0	0	32.18	3.06
July	0	0	0	0	0	0	0	0	3.94	0.37
August	0	0	0	0	0	0	0	0	3.94	0.37
Summer	0	0	0	0	0	0	0	0	13.13	1.25
December	0	0	1.31	0.12	89.31	8.49	139.21	13.24	90.62	8.62
January	0	0	7.88	0.75	102.44	9.74	174.68	16.61	61.07	5.81
February	0	0	5.25	0.50	77.49	7.37	102.44	9.74	143.81	13.68
Winter	0	0	5.25	0.50	87.34	8.31	137.90	13.12	101.13	9.62
	No Thermal Stress		**Moderate Heat Stress**		**Strong Heat Stress**		**Very Strong Heat Stress**		**Extreme Heat Stress**	
	Area	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**	**Area**	**Percentage**
June	179.93	17.11	59.10	5.62	149.07	14.18	533.88	50.78	97.19	9.24
July	195.69	18.61	47.28	4.50	202.26	19.24	602.17	57.28	0	0
August	203.57	19.36	61.07	5.81	286.97	27.30	495.79	47.16	0	0
Summer	191.75	18.24	54.50	5.18	195.03	18.55	596.92	56.78	0	0
December	730.22	69.46	0.66	0.06	0	0	0	0	0	0
January	705.27	67.08	0.00	0	0	0	0	0	0	0
February	671.12	63.84	51.22	4.87	0	0	0	0	0	0
Winter	719.72	68.46	0.00	0	0	0	0	0	0	0

The regional comfortable winter climate area accounted for 78.08%, of which about 87.68% reached the comfort level. The discomfort area only accounts for a small part, 21.92%, and the ratio of the "very strong cold stress" area only 0.5%.

To summarize, it can be seen that the area with a comfortable summer climate is relatively small in CPEC. In summer, only a few regions such as Karakoram can meet the demand as a summer resort. Therefore, the comfortable summer climate is a scarce resource in CPEC and has monopoly characteristics. Relatively speaking, the winter climate has a wide area of distribution and is a relatively ubiquitous resource.

4. Discussion

This paper provides research results on the differences between two types of pleasant climate characteristics and points out that the superiority of the development of climate resources not only lies in the comfort level and length of the comfort period but also is related to the types of pleasant climate, which have important practical significance for the site selection and development of tourist attractions and second residences. In recent years, there has been a rise in summer resorts and winter resorts in pleasant climates, as these are tourism resources that are sought after. However, the misjudgment of the superiority of climate resources can easily lead to blind investment. A comprehensive understanding of the distribution differences between different types of pleasant climates can guide people to invest in

tourism products related to summer or winter resorts. At present, there is no study on tourism climate comfort in the CPEC, so our method is the first to evaluate the climate suitability in the region.

Mountain resorts in the northern regions, which are winter sports resorts in the cold season and health tourism resorts during the hot season, are dominated by cold weather conditions. From this point of view, there are similar factors between the climate of the northern mountains and the northeast region of Romania [36]. They are numerous because they are located in the same climate (temperate zone).

On a seasonal scale, the Indus River Plain has very strong heat stress in summer. Although the altitude of the western plateau is higher and the thermal stress level has decreased, it still belongs to the "strong thermal stress" category. Therefore, to the south of Karakoram, the whole region experiences a strong thermal stress level in summer. The region comprises Karachi, Hyderabad, Multan, and other big cities, so there is a very strong summer demand for the CPEC in summer. In this region, there are also summer resorts represented by Karakoram and its nearby high-altitude area, which makes the region have both touristic climate resources and tourism demand. The existence of both resources and demand proves that regional summer tourism has a broad development prospect in summer. Compared with summer tourism, the demand for winter tourism is much smaller. In addition to Karakoram and Kashgar, the vast southern part of the CPEC is in the range of "no thermal stress" in winter and has the most comfortable climate conditions. The uncomfortable areas in winter are mainly distributed in areas with lower populations. Therefore, in the CPEC, there is little demand for winter tourism. However, in cold countries, such as Russia, the winter is long and cold. There is no winter resort in its territory. Karachi, as an international metropolis, has a very comfortable winter climate, which can provide cold-sheltering conditions for Russia and other countries. Therefore, in winter, although the market demand in the region is limited, some cities can be developed as typical international tourism cities.

For tourism management departments, it is necessary to encourage the location and design of tourism-related facilities and make rational use of tourism resources to adapt to the seasonal changes in tourism. For example, in the areas with a comfortable winter climate, various glacier tourism projects such as scenic spots, ski resorts, international ice, and snow festivals can be held. In the areas with a comfortable summer climate such as coastal areas, coastal sightseeing, sailing, diving, and other special tourism projects can be developed. At the same time, it is worth noting that, in addition to adapting to the seasonal changes in tourism, it is also necessary to strengthen the seasonal management of tourism. Departments should develop specific strategies to attract tourists throughout the year, and ensure year-round tourism opportunities for the region to promote sustainable tourism development. In this study, there are some deficiencies. The basic data of this study are based on the highest value of UTCI during the day. As we all know, the temperature at 14:00 p.m. local time is the daily maximum temperature. UTCI is affected by temperature to a certain extent, so the UTCI value at 14:00 is more likely to be the daily maximum value. However, due to the time limitation of reanalysis data, only the UTCI values of 11:00 and 17:00 PKT may affect the distribution characteristics of the whole region. In addition, the index UTCI has regional characteristics. The UTCI mainly considers the dressing habits of North America and Europe, and may not be consistent with Asians on this point, which may have a certain impact on the calculation results. At present, some cities such as Xi'an have adjusted the classification standard of thermal stress levels according to the local climate conditions [37]. However, because Xi'an can only represent the temperate monsoon climate, and the climate types in the CPEC are diverse, the standard of Xi'an is not of referential significance. Moreover, there are also some regional studies in Asia that also follow the original classification criteria [15,29,38,39], which proves that the original criteria have a certain referential significance on a regional scale. Thus, this paper still uses the original classification criteria. In future works, the adjustment of the regional UTCI classification standard for Asia must be addressed. Overall, in this paper, the mean radiation temperature was calculated using the radiation flux obtained from the simulation of cloud amount and temperature. There will be some errors in the results; however, it was found that the uncertainty

of four meteorological inputs in UTCI do not have a significant impact on the annual and seasonal thermal comfort assessment results [40].

When applying the research results of this paper to the tourism development of local climate resources, in reality, we should also consider the impact of tourism resource abundance and traffic accessibility on the tourism development potential of climate resources in different regions.

5. Conclusions

Based on the daily ERA-interim reanalysis data from 1979 to 2018, combined with the UTCI, the climate comfort index of summer and winter in CPEC was calculated, and the distribution characteristics and differences between pleasant summer and winter climates were deeply studied. The results show that:

(1) The comfortable summer climate is affected by middle–high latitudes or high altitudes. The comfortable summer climate regions of the CPEC were mainly distributed in Khyber Pakhtunkhwa in Pakistan and some regions of Xinjiang in China and also sporadically distributed in high-altitude mountains, such as the western plateau area. The comfortable winter climate regions were mainly distributed in vast areas, except for Karakoram and nearby areas. Compared with other countries and regions, altitude has the most significant impact on the distribution of a pleasant climate.

(2) The climate has spatial heterogeneity, and the two types of pleasant climates show obvious regional separation characteristics. There are few regions with dual attributes of comfortable summer and winter climates in CPEC.

(3) According to the calculation and comparison of the regional area of different climate comfort levels in summer and winter, it is found that the comfortable summer climate is scarcer in CPEC and is a monopoly resource, whereas the comfortable winter climate is widely distributed, meaning that it is a ubiquitous resource.

Author Contributions: Conceptualization: D.Z. methodology: D.Z. software: D.Z., Y.W. data curation: D.Z., H.L., M.D. writing—original draft preparation: D.Z. writing—review and editing: D.Z., J.W., Y.M., W.S. All authors have read and agreed to the published version of the manuscript.

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