RESEARCH ARTICLE

Associations between temperature variations and tourist arrivals: analysis based on Baidu Index of hot-spring tourism in 44 cities in China

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Abstract

Hot-spring tourism refers to entertainment, health preservation, commercial conferences, and other leisure activities at hot-spring locations. This tourism often shows periodic variability, which may be due to seasonal temperature variations. However, studies on the effects of temperature variations on tourist arrivals at hot springs are limited. Therefore, this study aimed to evaluate this relationship in 31 provincial capital cities and 13 s-tier cities in China. Using the Baidu Index, we obtained data for tourist arrivals to hot springs in each city and constructed a generalised additive model to explore the associations between temperature variations and tourist arrivals. We also analysed the statistical significance of the estimated effects during different seasons to explore potential effect modification. A 1 °C increase in temperature was associated with a 1.81% (95% confidence interval (CI): 1.69–1.93) decrease in daily tourist arrivals for hot-spring tourism. Significant positive associations between the abovementioned factors were observed in summer (2.18% change, 95% CI: 1.32–3.04). The effect of temperature on the volume of tourist arrivals may last for approximately 2 months. Robustness analysis confirmed the data reliability. The results indicate that significant relationships exist between temperature variations and hot-spring tourism arrivals, which vary seasonally. This study has significant implications for travel agencies to effectively manage tourist visits to hot spring locations.

Keywords Hot-spring tourism · Temperature · Tourist arrival · Baidu Index · Generalised additive model

Introduction

Hot-spring tourism is a developing form of tourism wherein hot-spring locations are utilised for conducting various activities, including entertainment, commercial conferences, health preservation, and leisure (Chen et al. 2011; Mi et al. 2019). Over the years, hot spring tourism

has become one of the most attractive tourism sectors globally, thereby attracting thousands of domestic and international tourists annually (Mi et al. 2019). With the rapid growth of economic and wellness tourism in China, people have begun to pursue new types of leisure (Xie et al. 2021). Hot-spring tourism is rapidly transforming into one of the most popular forms of leisure tourism (GWI 2019). It offers services such as spas, catering, healthcare, and other recreational activities (Hsieh et al. 2008; Kardeş 2021). In a sense, hot-spring tourism acts as a barometer for the local ecosystem, economy, and culture (Chaiyat et al. 2020; Channing 2017). Both environmental pollution and climate change could alter the temperature, pH, and microbes of hot springs, which would influence the ecological balance (Bennett Annastacia et al. 2022; Canora and Sdao 2022). Meanwhile, hot-spring tourism, which could provide different types of leisure and cultural experiences, has been sought after widely by the upper middle class (Chang et al. 2022; Wang and Lin 2021). Therefore, the income from hot-spring tourism is closely related to the local economy

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and culture. Over the last few decades in China, the high-speed growth of the economy has spawned huge numbers of the upper middle class, leading to numerous investments in tourism, which provides an unprecedented opportunity for developing fields such as hot-spring tourism (Liu et al. 2020). According to the 2018 Global Wellness Institute report, the hot-spring market has continued to grow as more people have relied on water and associated activities for stress-relieving, recovery, and social interaction (GWI 2019). As of 2017, the market has observed an increase of $5.2 billion in 2 years, and facilities have grown from 27,000 to 34,000 during the same period. China remains one of the most lucrative regions for hot springs, accounting for 31.2% of the global revenues in thermal/mineral spring tourism (GWI 2019; Mi et al. 2019).

According to a World Health Organization report, climate change has had the most significant influence on humans in this century (WHO 2018). Tourism is closely associated with the environment and climate, and it is more adversely affected by weather than other industries (Anna et al. 2021; Matthews et al. 2021; Wang et al. 2020). Economists, tourism enterprises, and news media have different opinions on whether the weather affects the tourism industry. It is generally believed that climate change will lead to an increase in extreme weather conditions, such as storms, heat waves, or intense and prolonged rainfall, which will harm tourist experiences (Hewer 2020; Hübner and Gössling 2012; Sibitane et al. 2022). However, Marshall et al. (2013) found that many tourism operators can offset weather vulnerability by developing reasonable climate adaptation plans. These findings have the capacity to stimulate research and development on climate-resilient tourism (Scott and Gössling 2022). Most existing studies have focused on the association between weather events and outdoor tourism, indicating that variations in meteorological factors may have an immediate or delayed impact on the outdoor tourist market (Craig and Feng 2018; R.-Toubes et al. 2020; Wang et al. 2018). However, the water temperature of most hot springs is generally not affected by environmental temperature (Yan et al. 2017). Therefore, existing studies have neglected the fact that the effects of environmental temperature variations on hot springs may differ from those of outdoor scenic spots, and the same strategies should not be used to cope with environmental temperature variations in the case of hot springs. To bridge this gap, this study aims to examine the impact of environmental temperature variations on hot-spring tourism.

The data on tourist volumes are usually accurate but difficult to obtain in a timely manner. Therefore, these data are unsuitable for modelling and analysis (Xie et al. 2021). Some scholars have emphasised that online search data can reflect tourist behaviour and provide a new and accurate method for tourism research (Yang et al. 2015). In the last

few decades, search engines, including Baidu and Google, have opened a new era in various social disciplines. Search engines provide information (scenic spot introduction, tourism service products, traffic routes, etc.) for people while recording their online search behaviours, which represent potential tourist demands. Compared with traditional statistics or survey data, these online search data have advantages including greater representativeness, timing, and availability (Yao et al. 2021; Zhang et al. 2021). Thus, we used the Baidu Index to analyse the effects of environmental temperature variations on tourist arrivals at hot-spring scenic spots in 31 provincial capital cities and 13 s-tier cities in China from 2017 to 2019, and seasonal modifications on the effects were also examined.

Materials and methods

Baidu Index

Baidu (www.baidu.com) is the most popular search engine in China. The Baidu Index was launched to provide the daily Internet search frequency data of different keywords. It is a massive data-sharing platform reflecting 'user awareness' and 'media attention' of different keywords. The Baidu Index serves a similar function as the Google Index. One can enter keywords in the Baidu Index search bar, selecting the searched time, range, and region, clicking on the 'Baidu' button, and then obtaining the keyword's daily search volume within the corresponding period and region.

Since the collection and publication of actual travel data often lag well behind events and can be based on insufficient sample numbers, Chinese scholars began to explore the use of Internet data to substitute for traditional statistical data. Through empirical studies on different Internet data sources (e.g., Baidu, Google, Airbnb, TripAdvisor, and Ctrip) and different types of tourism destinations, the Baidu Index was found to have a stronger correlation with tourist arrivals in China than other indices (Pearson correlation coefficient > 0.75) (Huang et al. 2017; Sun et al. 2019). People may sometimes visit scenic spots without searching for them online, and other times they may search for tourist attractions online without visiting them. Nonetheless, this research still shows that there is a long-term equilibrium relationship and Granger causality relationship between the observed number of tourists and related keywords in the Baidu Index. It was confirmed that the research conclusions were valid when using the Baidu Index. Thus, increasing studies began to adopt the Baidu Index as a substitution variable for tourist arrivals (Li et al. 2020; Wang et al. 2020; Xie et al. 2021; Yao et al. 2021).

Study area

This study was conducted in 44 cities in China (including 4 municipalities, 27 provincial capital cities, and 13 s-tier cities). The second-tier cities included in this study refer to the second-largest city in each province; further, cities lacking the Baidu Index or weather data were excluded. Figure 1 shows the cumulative Baidu Indices for these cities from 2017 to 2019. We focused on Mainland China because Baidu is not the first choice of search engine in Taiwan, Hong Kong, and Macao. We set 2019 as the endpoint of the study period to avoid the impact of the COVID-19 pandemic on the tourism industry.

Data collection

After referring to related literature, this study selected three possible keywords (hot spring, hot spring tourism, and hot spring spots) (Wang et al. 2020; Xie et al. 2021; Yang et al.

2015). The search records of these keywords in 44 cities in China from 2017 to 2019 were obtained from Baidu (https://index.baidu.com) and were generated from two sources: personal computers (PC trend) and mobile terminals. Owing to the comprehensive nature of this research, the sum of these two sources (overall trend) was selected as the dependent variable.

Weather data were obtained from the National Meteorological Information Center (http://data.cma.cn) and included daily average temperature (°C), relative humidity (%), wind speed (m/s), rainfall (mm), and sunshine duration (h). These meteorological factors have been shown to have important impacts on tourist travel decisions (Givoni et al. 2003).

Statistical analysis

Previous studies have employed various methods to investigate the relationship between weather and tourism. Many researchers who are interested in the impacts of extreme weather
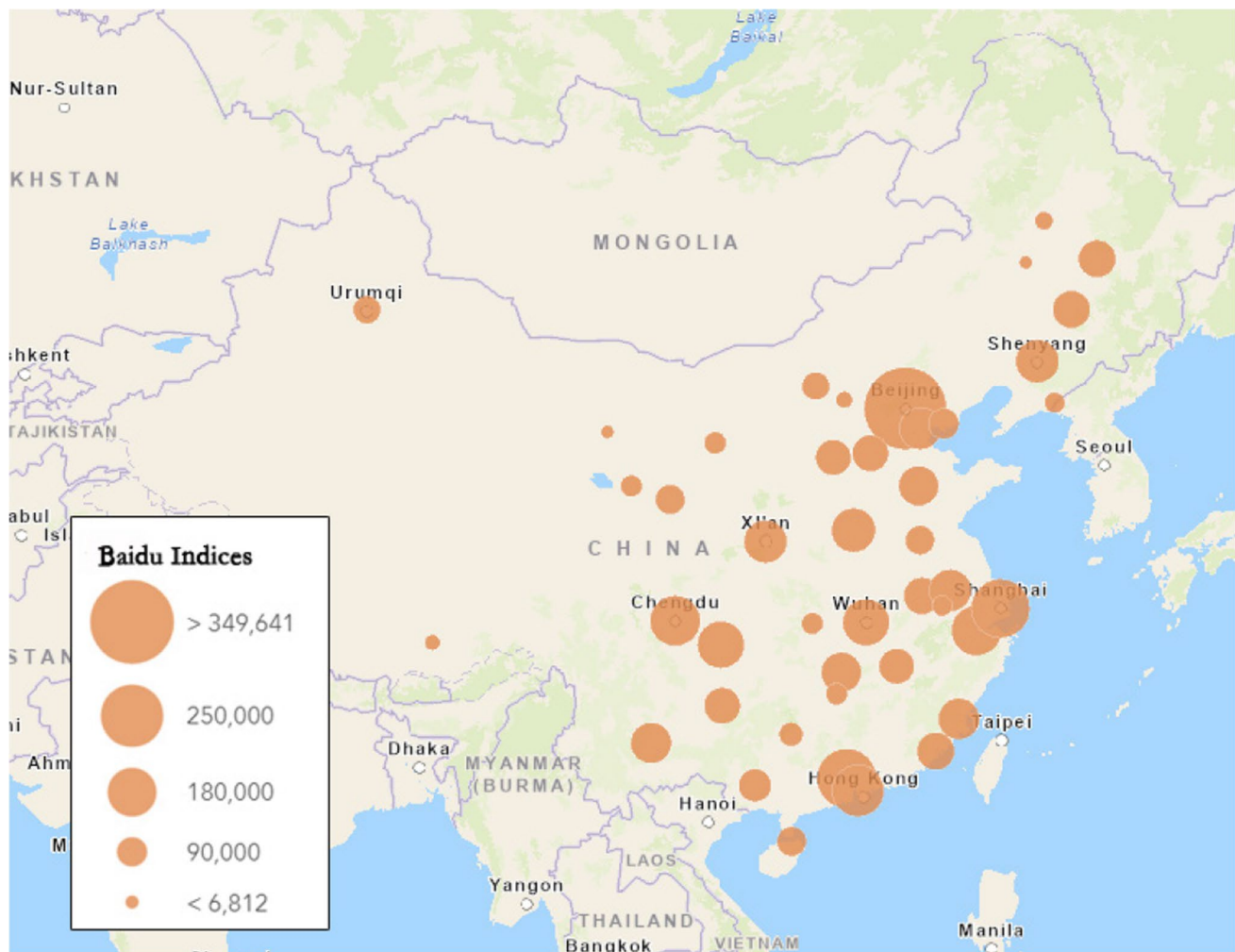
Fig. 1 Locations of 44 cities and cumulative Baidu Indices for each city from 2017 to 2019
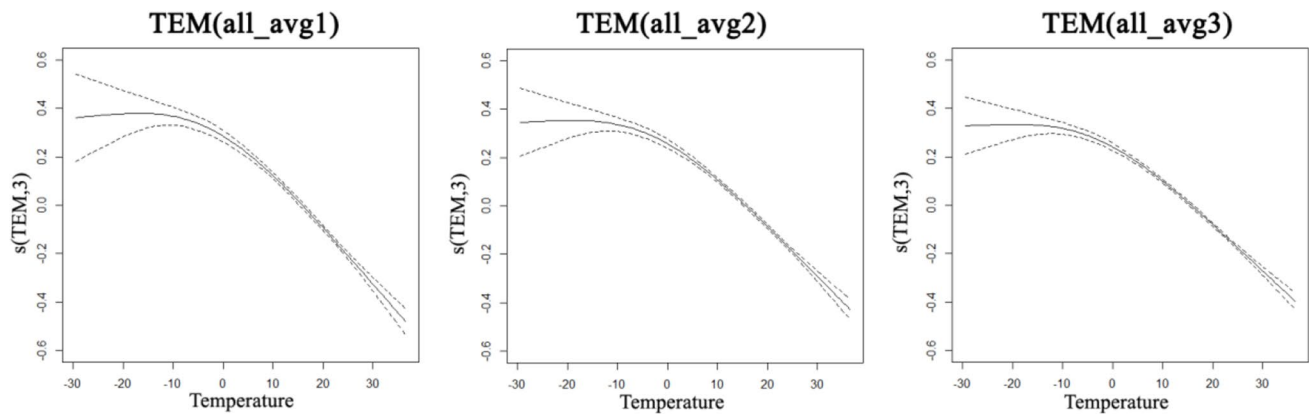
Fig. 2 Exposure–response curves of temperature and daily tourist arrivals using the multiple meteorological variable model. The x axis indicates the temperature, and the y axis represents the contribution of the smoother to the fitted values

events are likely to use analysis models with classified variables (Hewer 2020; Hübner and Gössling 2012; Sibitane et al. 2022). Some linear models are also widely used to estimate the impact of meteorological variables on tourism (Ciobotaru et al. 2019; Serquet and Rebetez 2011; Wilkins et al. 2017). However, other studies have shown that the relationships between climate factors and people's behaviour are generally nonlinear (Moral-Carcedo and Vicéns-Otero 2005; Theofilatos and Yannis 2014; Yoon 2019). Therefore, effective nonlinear models are needed to solve such problems.

The generalised additive model (GAM) is an extension of the generalised linear model (GLM). GAMs provide more flexibility than GLMs, as the former relax the assumption of linearity while retaining coherent inference between the dependent and independent variables (Reiss 2006). Thus, GAMs are widely used in examining the associations between meteorological factors and tourism (Fotiadis et al. 2021; Saenz-de-Miera and Rosselló 2014; Sottini et al. 2021; Tiwari et al. 2021; Yoon 2019) owing to their ability to describe static nonlinearities, i.e. nonlinear effects that are stable over time (Aldrin and Haff 2005). Furthermore, GAMs can incorporate new components with a simple additive transformation, which makes them easy to interpret.

The main drawback of GAMs lies in the estimation of smooth functions, and there are different ways to address this (Barrio et al. 2013). One of the most common alternatives is based on splines, which allow the GAM estimation to be reduced to the GLM context (Currie et al. 2006). Thin-plate regression splines have been frequently chosen for their advantages in minimising squared residuals and increasing prediction precision (Yoon 2019). In cases without clear prior knowledge of their functional form and knot locations, this type of spline finds an optimal solution balancing the fidelity to the data and smoothness of the function (Wood

2006). In addition, since the daily count of the Baidu Index approximately followed a Gaussian distribution, we estimated the associations between temperature variations and tourist arrivals by creating a GAM with a Gaussian family, and then we selected the thin-plate regression splines for the meteorological variables.

By considering the precursory nature of online searches on tourism behaviour and the impact of the weather forecast on online searches, we measured the volume of tourist arrivals with a 1-day Baidu Index (all_avg1), 2-day (today and yesterday) Baidu Index (all_avg2), and 3-day (today, yesterday, and the day before yesterday) Baidu Index (all_avg3) (Wang et al. 2020). First, we investigated the effects of temperature in a single meteorological variable model without other weather factors to avoid collinearity (Zhang et al. 2019). The basic model used was as follows:

$$\ln\left(all\_avg_{i,t}\right) = \alpha + TEM_{i,t} + city_i + year_y + DOW_t + Holiday_t \quad (1)$$

where $all\_avg_{i,t}$ is the tourist arrivals (all_avg1, all_avg2, and all_avg3) for hot springs in city i on day t, $ln(\cdot)$ refers to the log link function, α is the intercept, $TEM_{i,t}$ is the daily average temperature in city i on day t, $city_i$ indicates city i, $year_y$ indicates year y (2017–2019), DOW_t indicates the day of the week (Monday to Sunday), $Holiday_t$ indicates public holidays (yes, no), $i = 1, 2, …, 31$, and $t = 1, 2, …, 1095$.

In Model (1), only the temperature was considered a parameter for the analysis, and the association between the dependent and independent variables was presumed to be linear. However, tourists might also consider other weather factors before planning their travel, and the relationships between meteorological variables and tourist arrivals are probably nonlinear; thus, all meteorological variables and thin-plate regression splines were introduced into Model (1) to obtain Model (2), as follows:

$$ln\left(all\_avg_{i,t}\right) = \alpha + s\left(TEM_{i,t}\right) + s\left(RHU_{i,t}\right) \\ + s\left(WIN_{i,t}\right) + s\left(RAF_{i,t}\right) + s\left(SSD_{i,t}\right) \quad (2) \\ + city_i + year_y + DOW_t + Holiday_t$$

where $s(\cdot)$ indicates the thin-plate regression splines (with the use of spline, the function becomes less smooth but more flexible, providing a better fit to the data); $RHU_{i,t}$, $WIN_{i,t}$, $RAF_{i,t}$, and $SSD_{i,t}$ refer to relative humidity, wind speed, rainfall, and sunshine duration in city i on day t, which were previously noted to be related to tourist experience and comfort (Matzarakis 2006); and $ln\left(all\_avg_{i,t}\right)$, $city_i$, $year_y$, DOW_t, and $Holiday_t$ are the same as in Model (1).

Figure 2 displays the exposure–response curves of temperature and daily tourist arrivals in Model (2). The results suggest that the relationship between temperature and tourist arrivals was approximately linear, illustrating that the assumptions in Model (1) were acceptable. Thus, we modified Model (2) to quantitatively evaluate the percentage change in tourist arrivals correlated with the temperature variations:

$$ln\left(all\_avg_{i,t}\right) = \alpha + TEM_{i,t} + s\left(RHU_{i,t}\right) \\ + s\left(WIN_{i,t}\right) + s\left(RAF_{i,t}\right) + s\left(SSD_{i,t}\right) + city_i \quad (3) \\ + year_y + DOW_t + Holiday_t$$

Furthermore, we examined the possible effect of temperature change according to different seasons (spring, March to May; summer, June to August; autumn, September to November; and winter, December to February).

The time lags between temperature and tourist arrivals were also examined. Tourist arrivals exhibit a distinct monthly cycle, and cyclical changes may be incorrectly associated with temperature variations (Yoon 2019). Therefore, this study explored the lag in impact up to 30 days after temperature variations to determine whether the effects were immediate or delayed.

The monthly effect of temperature on tourist behaviour should also be considered. Thirty days may not capture the true association between searches, which occur at the planning stage, and actual travel, which occurs months after the initial searches. Considering the seasonal effects on hotspring tourism, we set 3 months as the maximum lag period and defined the monthly model as follows:

$$ln\left(all\_avg_{i,m}\right) = \alpha + TEM_{i,m} + s\left(RHU_{i,m}\right) \\ + s\left(WIN_{i,m}\right) + s\left(RAF_{i,m}\right) + s\left(SSD_{i,m}\right) \quad (4) \\ + city_i + year_y$$

where $all\_avg_{i,m}$ indicates the total tourist arrival (monthly sum of all_avg1, all_avg2, and all_avg3) for hot springs in city i in month m and $TEM_{i,m}$, $RHU_{i,m}$, $WIN_{i,m}$, $RAF_{i,m}$, and $SSD_{i,m}$ are the monthly average values of the meteorological variables in city i in month m.

Three sensitivity analyses were then conducted to test the robustness of the results. First, the conclusion was re-evaluated using the PC trend as the dependent variable. Second, the independent variable was re-evaluated in East China. Third, the sample size was reduced from 2017 to 2018. All analyses were performed using R software (version 3.6.3; R Development Core Team, Vienna, Austria) and the mgcv package (version 1.8–35). Statistical significance was set at $P < 0.05$ for all analyses. The estimated effects are shown as percentage change (%) in tourist arrivals associated with a 1 °C increase in temperature.

Results

Data description

Table 1 shows the descriptive statistics for the daily tourist arrivals and meteorological variables. The locations and Baidu Indices of each city are listed in Supplementary Table S1. The dataset included 45,398 valid records from 44 cities. During the observation period, this study included 4,954,649 search records with an average of 109.14. The Baidu Index was found to be the highest in the winter. The averages of daily mean temperature, relative humidity, wind speed, rainfall, and sunshine duration were 14.35 °C, 65.54%, 2.25 m/s, 2.54 mm, and 5.81 h, respectively. As the most developed cities in China, Beijing (349,641 times), Guangzhou (236,092 times), and Shanghai (233,969 times) had the highest number of search records. There were a higher number of records in central, southern, and eastern China as compared to western and northern China. According to the Spearman correlation analysis (Table 2) conducted in this study, the correlation coefficients between temperature and other meteorological variables were small.

Relationship between temperature and tourist arrivals

Figure 2 shows the associations between temperature and daily tourist arrivals in the multiple meteorological variables model. Above − 10 °C, tourist arrivals began to decrease rapidly with increasing temperature. However, the 95% confidence interval (CI) was quite wide below − 10 °C, and the statistical significance of the result was uncertain for this segment.

Figure 3 illustrates the effect of temperature variations on the all_avg1 values, and Table S1 shows the specific values. The all_avg1 values were negatively correlated with an increase in temperature (percentage change (%): − 1.81,

Table 1 Descriptive statistics of daily tourist arrivals and meteorological variables across all cities, from January 2017 to December 2019

Variables	Sum	Mean	SD	Min	25th	50th	75th	Max
Baidu Index								
All seasons	4,954,649	109.14	75.07	0.00	59.00	122.00	143.00	1049.00
Spring	1,149,819	94.68	61.68	0.00	57.00	116.00	135.00	586.00
Summer	1,049,569	97.87	56.62	0.00	58.00	117.00	135.00	348.00
Autumn	1,198,024	110.63	70.54	0.00	60.00	123.00	145.00	588.00
Winter	1,557,237	135.68	97.05	0.00	63.00	132.00	170.00	1049.00
Tourist arrivals with Baidu Index								
all_avg1	4,954,649	109.14	75.07	0.00	59.00	122.00	143.00	1049.00
all_avg2	4,955,502	109.16	72.61	0.00	59.00	112.50	142.50	1037.00
all_avg3	4,956,451	109.18	71.71	0.00	59.67	109.33	142.00	973.33
Meteorological variables								
TEM (°C)	-	14.35	11.37	−29.40	6.90	16.20	23.40	36.50
RHU (%)	-	65.54	19.31	8.00	52.00	68.00	81.00	100.00
WIN (m/s)	-	2.25	1.06	0.00	1.50	2.10	2.80	10.30
RAF (mm)	-	2.54	9.24	0.00	0.00	0.00	0.30	266.60
SSD (h)	-	5.81	4.19	0.00	1.10	6.80	9.30	14.60

Spring, March to May; summer, June to August; autumn, September to November; winter, December to February; *all_avg1* tourist arrivals with 1-day Baidu Index, *all_avg2* tourist arrivals with 2-day Baidu Index, *all_avg3* tourist arrivals with 3-day Baidu Index, *TEM* temperature, *RHU* relative humidity, *WIN* wind speed, *RAF* rainfall, and *SSD* sunshine duration

Table 2 Spearman correlation coefficients between temperature and other meteorological variables across all cities, from January 2017 to December 2019

Variables	TEM	RHU	WIN	RAF	SSD
TEM	1.00	0.28	−0.02	0.14	0.15
RHU	<0.01	1.00	−0.22	0.59	−0.59
WIN	<0.01	<0.01	1.00	−0.02	0.11
RAF	<0.01	<0.01	<0.01	1.00	−0.51
SSD	<0.01	<0.01	<0.01	<0.01	1.00

TEM temperature, *RHU* relative humidity, *WIN* wind speed, *RAF* rainfall, *SSD* sunshine duration; r-value in the upper right triangle and *p*-value in the lower left triangle

95% CI: −1.93 to −1.69), which implied that a 1 °C increase in temperature was associated with a decrease in tourist arrivals by 1.81%. We also observed continuous significantly negative correlations between temperature and tourist arrivals at a lag of 0–30 days, as the 95% CIs were consistently below the zero point. Temperature variations showed positive associations with tourist arrivals in summer (percentage change (%): 2.18, 95% CI: 1.32 to 3.04), and the 95% CIs were above the zero point at a lag of 0–28 days. The relationship between temperature and tourist arrivals peaked at a lag of 14 days in summer (percentage change (%): 2.97, 95% CI: 2.10 to 3.84) and reached a nadir at a lag of 18 days in winter (percentage change (%): −2.92, 95% CI: −3.50 to −2.35). The differences between these two extrema and percentage changes in other seasons are significant (Table 3). The relationship

between all_avg2, all_avg3, and temperature variations showed a similar trend to that of all_avg1 (Tables S3 and S4).

Figure 4 displays the monthly associations of temperature variations according to Model (3). The decrease in temperature was significantly associated with an increase in the volume of tourist arrivals in the current month and the following month (lag 0: 3.71, 95% CI: 0.71 to 6.72; lag 1: 7.19, 95% CI: 2.83 to 11.56). The percentage change was higher in the following month than in the current month, but the 95% CIs overlapped. The 95% CI contained the zero point at a lag of 2–3 months, and the statistical significance of the result was uncertain for this segment. The specific values are listed in Table S5.

Robustness test

The results of the robustness analysis are shown in Fig. 5. Overall, the associations between temperature variations and tourist arrivals were robust to variations in the Baidu Index types, study area, and sample range, the specific values of which are listed in Table S6.

Discussion

In this study, we employed the GAM to estimate the relationship between temperature variations and daily tourist arrivals for hot-spring tourism in 44 cities in China. Hot-spring tourism is more popular in central, southern,
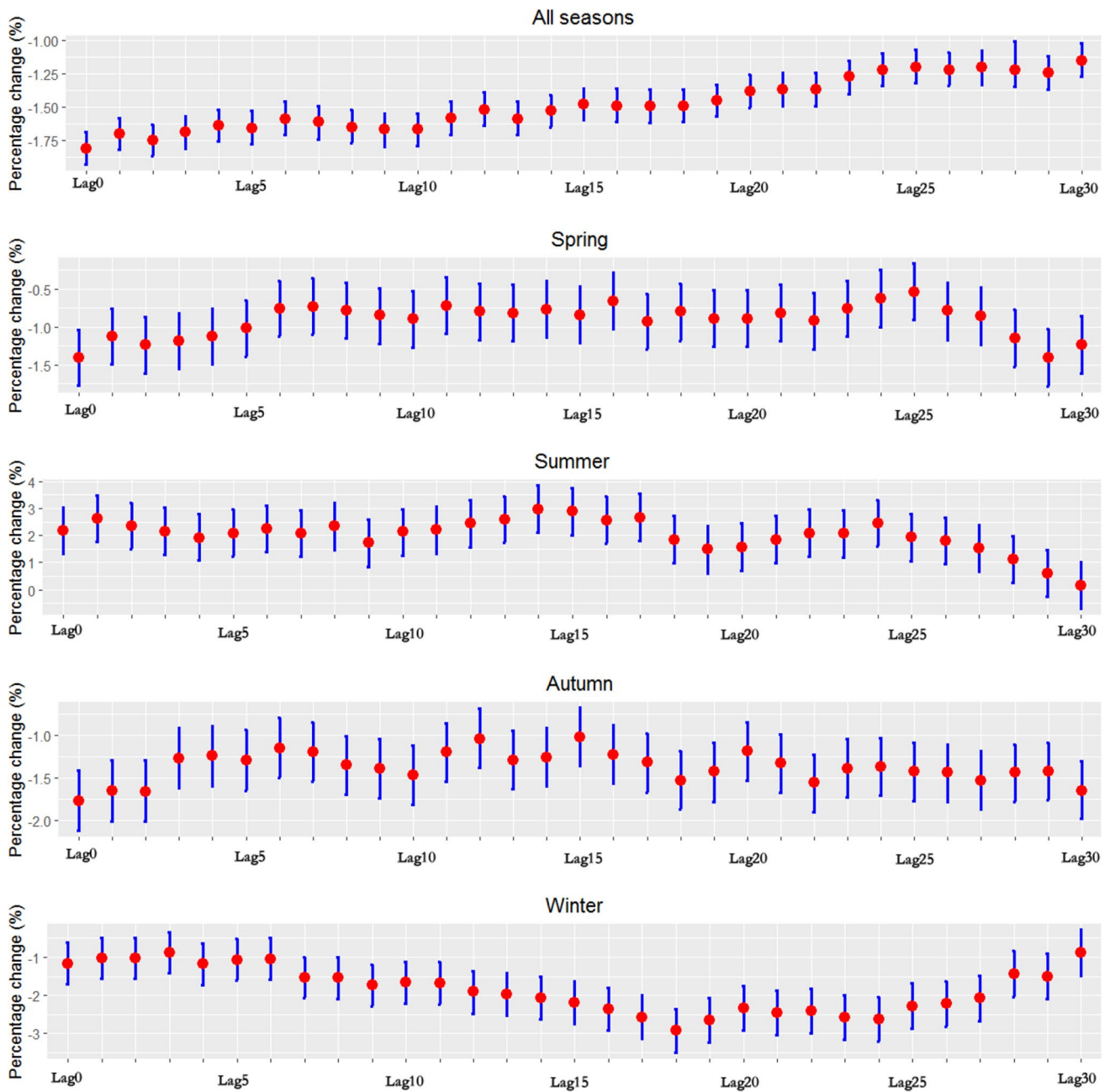
Fig. 3 Percentage change (%) and 95% CI of daily tourist arrivals associated with 1 °C increase in temperature using the multi-meteorological variables model on 0–30 lag days

and eastern China. The daily Baidu Index was used as the substitution variable for tourist arrivals to hot springs and identified an approximately linear relationship between daily average temperature and hot-spring tourism. Tourist arrival increased as the temperature decreased. The significant association between the temperature decrease and volume of tourist arrivals persisted for 2 months. The associations showed significant seasonal variation; for example, summer was found to have the opposite trend. According to the robustness analyses, the results were reliable. This

study can help us understand the impact of temperature on tourism and provide useful experience on scenic spots for policymakers to implement adequate measures to cope with temperature variations.

The impact of ambient temperature on economic sectors, especially those involving human behaviour and activities, is not well understood, but tourism is a sector in which this form of research has been conducted more frequently. The decrease in temperature can be perceived by tourists as a potential health risk or disruption to their
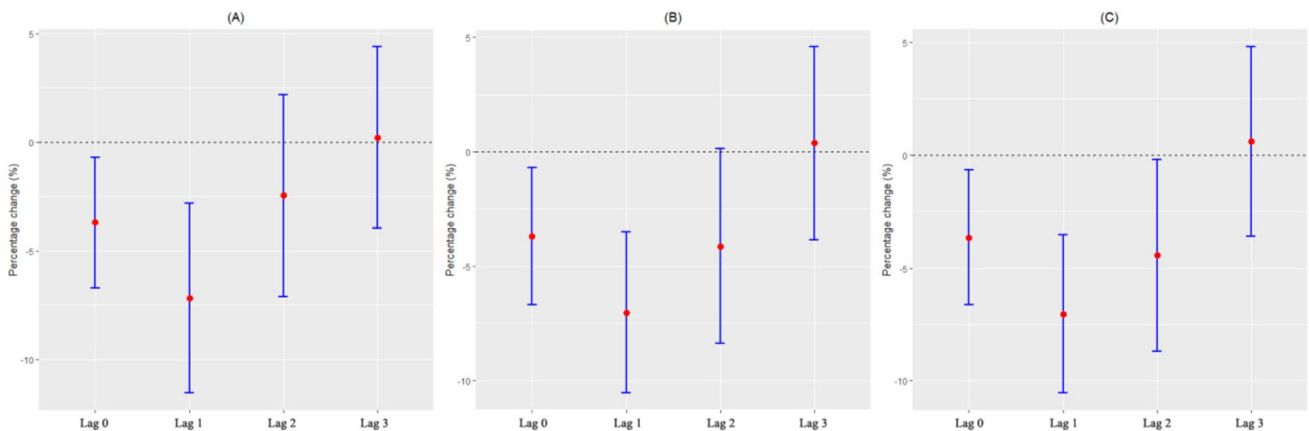
Table 3 Extremum of percentage change (%) and 95% CI of daily tourist arrivals with 1-day Baidu Index associated with 1 °C increase in temperature in different seasons

	Lag[a]: Percentage change (%) and 95% CI	
	Maximum value	Minimum value
All seasons	Lag30: − 1.15 (− 1.27, − 1.02)	Lag0: − 1.81 (− 1.93, − 1.69)
Spring	Lag25: − 0.54 (− 0.91, − 0.17)	Lag29: − 1.41 (− 1.78, − 1.03)
Summer	**Lag14: 2.97 (2.10, 3.84)**	Lag30: 0.17 (− 0.69, 1.03)
Autumn	Lag15: − 1.02 (− 1.36, − 0.68)	Lag0: − 1.77 (− 2.12, − 1.41)
Winter	Lag30: − 0.88 (− 1.49, − 0.28)	**Lag18: − 2.92 (− 3.50, − 2.35)**

[a]*Lag* lag days; extremum were labeled in bold font

tourism experience, leading to changes in travel plans (Ciobotaru et al. 2019; Fisichelli et al. 2015; Friedrich et al. 2020; R.-Toubes et al. 2020; Tervo 2008). In contrast, our study found that hot-spring tourism follows the opposite trend. The impact of weather changes on tourist spots is usually considered immediate (Matthews et al. 2021; R.-Toubes et al. 2020). However, a continuous significant association between temperature variations and tourist arrivals at hot springs was observed in our study. Finally, high summer temperatures have a negative impact on most scenic spots (Day et al. 2021; Hewer 2020). Unexpectedly, tourist arrivals to hot springs increased as the temperature increased in summer in the study area.

An increasing number of studies have dealt with several aspects of tourism seasonality, causes, and impacts (Giachino et al. 2020; Lozano et al. 2020; Vatsa 2021). As a natural tourist destination, seasonal peaks in hot-spring

Fig. 4 Percentage change (%) and 95% CI of monthly tourist arrivals associated with 1 °C increase in monthly average temperature using the multi-meteorological variable model over 0–3 lag months, the baseline of zero point is represented by dashed line: **a** results of monthly tourist arrivals with 1-day Baidu Index, **b** results of monthly tourist arrivals with 2-day Baidu Index, and **c** results of monthly tourist arrivals with 3-day Baidu Index
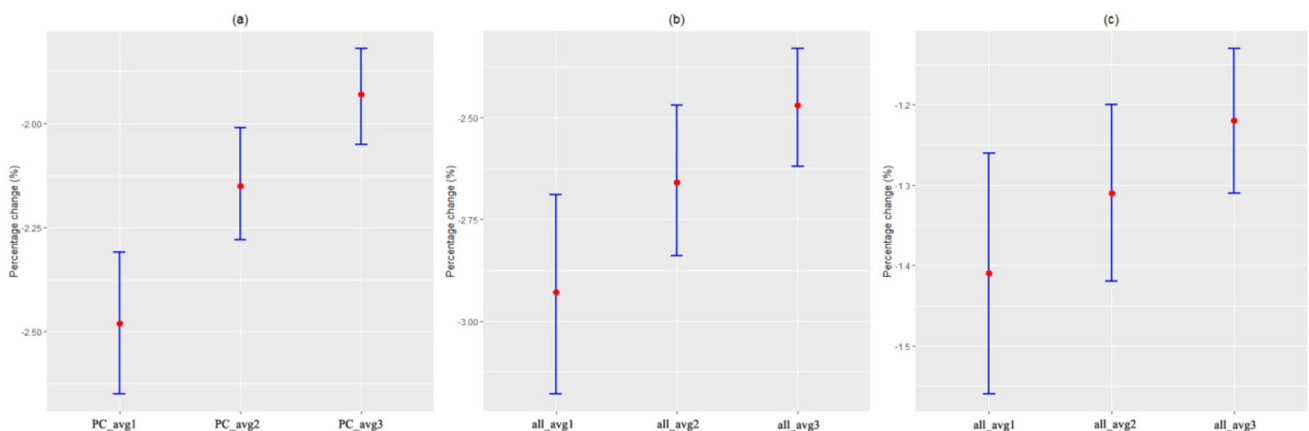
Fig. 5 Robustness test for temperature using the multi-meteorological variable model: **a** effects measured with the PC trend of Baidu Index, **b** effects measured throughout East China, and **c** effects measured during 2017–2018

spots have been observed worldwide and are widely discussed. For example, Hsieh et al (2008) found that winter is the peak season for hot-spring tourism, whereas summer is the off-season. However, another study found that hot springs have distinct winter and summer seasonal characteristics (Yu and Wang 2020). In the present study, seasonal patterns were also observed in online searches for hot-spring tourism in China (Table 1). According to the analysis, there may be regional differences in the seasonality of hot-spring tourism. Temperature, as the strongest indicator of domestic tourism, may trigger fluctuations in hot-spring tourism (Bigano et al. 2005). Additionally, significant regional differences were observed (Fig. 1). In central, southern, and eastern China, the high-speed economic growth and large populations provide incomparable opportunities for the hot-spring tourism market (Alfarhan et al. 2022; Min et al. 2016).

Based on the push–pull theory (Dann 1981), an influential theory in tourism, factors affecting tourist behaviour can be summarised as push and pull (Wang et al. 2020). Tourist motivations such as cultural experience and physical and mental relaxation belong to 'push' factors. The attractiveness of the destination, including the environment, food, and distinctive culture, belongs to the 'pull' factor (Jafari and Dann 2015). According to the theory, temperature variations in residential locations play a 'push' role that can promote the 'escape' of tourists from the city. Conversely, a pleasant hot-spring environment plays a positive role in attracting more tourists.

The above discussion clarifies the reason for the significant increase in tourist arrivals at hot springs when environmental temperature decreases. From a biological perspective, possible pathways linking exposure to a low-temperature environment with human discomfort may involve organ injuries caused by a decrease in the core body temperature (Min et al. 2021; Xu et al. 2021). One study suggested that, in temperate regions, warm conditions could promote human thermal comfort (Lin 2009). Hot springs can regulate core body temperature and glucocorticoid concentrations in humans and create physically and mentally pleasant conditions for people in cold environments (Takeshita et al. 2018). The water temperature of hot-spring resorts in China ranges between 30 and 60 °C, and the partial maximum temperature can reach 80 °C (Guo et al. 2020; Wu et al. 2021). This can lead to a warm and comfortable environment under cold weather conditions. Another related study indicated that most hot springs were formed by tectonic terrain depression, which could protect the spa from cold winds in autumn and winter (Valjarević et al. 2017). Therefore, hot-spring spots can provide a suitably warm environment in cold-wave weather, which has a strong 'pull' effect on tourists.

Interestingly, the effect of the temperature decrease was less significant in extremely cold weather (below − 10 °C). It is known that people significantly reduce their outdoor activities during extremely cold weather (Alberto et al. 2021). This can improve thermal comfort in severely cold weather and reduce the damage caused by low temperatures (Coccolo et al. 2016; Yin et al. 2021). Furthermore, ice and snow on the roads will cause inconvenience to traffic, which may reduce the desire of people to travel (Datla and Sharma 2010).

Notably, it was observed that the number of tourists visiting hot springs increased significantly with an increase in temperature in summer. Therefore, hot weather may have increased the attractiveness of hot-spring tourism to urban residents. Under global warming, cool-weather tourism has become popular during hot summers (Demiroglu and Hall 2020; Førland et al. 2013). Tourists carefully consider the temperatures of their destinations when planning their travel. The water temperature of hot springs is constant throughout the four seasons. Moreover, hot springs provide good water quality and various chemical ions. In addition, the indoor environment of hot-spring spots can reduce the harmful effects of solar radiation on the human body (Lee et al. 2020). Thus, hot-spring tourism can provide urban residents with a pleasantly cool environment and different types of natural locations in summer, which improves the well-being and vitality of people (Korpela et al. 2017).

As shown in Fig. 3 and Table 3, the relationships between hot-spring tourism and temperature variations are more significant in the summer and winter seasons. The estimations of seasonal differences are consistent with theoretical expectations, illustrating that tourists may have a stronger desire to go to hot springs in extreme temperature weather. This result could be explained by the 'push' effect of extreme temperature and the 'pull' effect of hot springs. The pursuit of thermal comfort was the primary factor in promoting tourist arrivals (Budiawan and Tsuzuki 2021; Huang et al. 2019). The appeal of hot-spring attractions in extreme temperature weather is widely observed globally (Li and Chi 2014; Takeshita et al. 2018). Thermal sensitivity is another important factor affecting tourists' intentions. One study on the 'thermal acceptable range' showed that the fitted curve of thermal unacceptability and temperature variations is approximately U-shaped (Cohen et al. 2013). Accordingly, people are more sensitive to each 1 °C change in cold and hot seasons, which is consistent with our results.

The above findings indicate that the motivation of tourists may vary with changing seasons. Therefore, hot-spring scenic spots should provide different tourism products and adopt different marketing strategies in different seasons (Grossi and Mussini 2021; Li and Chi 2014). The marketing

departments could also develop some cultural and entertainment products to weaken the seasonality of hot-spring scenic spots (Gvozdjáková et al. 2022; Zhang et al. 2022).

Additionally, we observed a continuous significant association between temperature variation and tourist arrivals at hot springs within 2 months. We speculated that some people may not go to hot-spring spots immediately after cooling down but may make travel plans after many weeks. Surprisingly, it was observed that the change in tourist arrivals related to temperature variations was slightly higher in the second month of a 2-month interval. This phenomenon may be caused by multiple visits by local tourists (Tan 2017). These previous visitors may consider a second visit due to attractions or experiences that they missed during their first visit or to relive the experience they had. Thus, repeat visitation is a cost-effective and desirable market segment for the hot-spring marketing department (Maghrifani et al. 2022). The marketing department should formulate strategies to improve repeat tourist engagement, experience, and value cocreation, which may help to increase the number of repeat visits (Rather et al. 2022; Tan 2017). However, these findings remain inconclusive and require further investigation in a larger population.

To the best of our knowledge, this is the first study to examine the effect of ambient temperature on hot-spring tourism in multiple cities in China. This study constructed GAMs to estimate the associations between temperature variations and tourist arrivals to hot springs, providing a new perspective on climate change and tourism research. This result contributes to the tourism industry in three ways: First, such findings provide evidence for tourism authorities to reacquaint themselves with the impacts of weather and adopt coping strategies to increase tourism income. Public authorities can report the influence of weather on different scenic spots via the Internet and help tourists rationally make travel plans (Wang et al. 2020). Second, tourism enterprises should adjust and upgrade their products and services and conduct more publicity to minimise the adverse effects of climate change. For hot-spring spots, health and entertainment elements can be integrated according to the climate to attract potential visitors (Gvozdjáková et al. 2022). Finally, tourists should change their stereotypical attitude of travelling only in fine weather and choose their preferred scenic spots according to different weather conditions.

Despite these important findings, our study had several limitations. First, the effects of temperature variations during different seasons were adequately considered in our study. However, we lacked the characteristics of tourists (demographic and socioeconomic information) and could not explore the impact of weather from more perspectives. Second, we analysed only the overall demand for hot-spring tourism. Therefore, the demand for hot-spring tourism in new markets and for various types of tourism products needs to be further investigated. Third, using the Baidu Index instead of the actual travel data may lead to measurement errors. However, these measurement errors rarely affect the consistency of the estimations, possibly because there is a sufficient empirical basis for employing the Baidu Index as the substitution variable for tourist arrivals. Specifically, existing studies have shown an equilibrium relationship between the Baidu Index and tourist volume (Huang et al. 2017; Li et al. 2020; Yao et al. 2021). Finally, similar to the Baidu Index, social media data, such as those extracted from microblogs and Twitter, might also be utilised.

Conclusion

Based on panel data, this study analysed the association between temperature variations and daily tourist arrivals in hot-spring tourism. We adopted the daily Baidu Index as the substitution variable for tourist arrivals to hot springs. This study suggests that environmental temperature is negatively associated with tourist arrivals at hot springs, where a decreasing temperature leads to an increase in tourist arrivals. However, the effects of temperature variation differ depending on the season. Moreover, the significant association between temperature variation and tourist arrivals is continuous. These findings could provide valuable information on hot-spring spots, which may have implications for travel agencies that manage tourist visits.

Declarations

Ethical approval Not applicable.

Consent to participate Not applicable.

Consent to publish Not applicable.

Competing interests The authors declare no competing interests.

References

Alberto IC, Jiao Y, Zhang X (2021) Too hot or too cold to study? The effect of temperature on student time allocation. Econ Educ Rev 84:102152. https://doi.org/10.1016/j.econedurev.2021.102152

Aldrin M, Haff IH (2005) Generalised additive modelling of air pollution, traffic volume and meteorology. Atmos Environ 39(11):2145–2155. https://doi.org/10.1016/j.atmosenv.2004.12.020

Alfarhan UF, Olya H, Nusair K (2022) How do prosperity and aspiration underlie leisure tourism expenditure patterns? Tourism Econ 13548166211064215. https://doi.org/10.1177/13548166211064215

Anna B, Milica P, Oleh S, Błażejczyk K, Olesya S (2021) Weather suitability for outdoor tourism in three European regions in first decades of the twenty-first century. Int J Biometeorol 65:1339–1356. https://doi.org/10.1007/s00484-020-01984-z

Bennett Annastacia C, Murugapiran Senthil K, Kees Eric D, Sauer Hailey M, Hamilton Trinity L (2022) Temperature and geographic location impact the distribution and diversity of photoautotrophic gene variants in alkaline Yellowstone hot springs. Microbiol Spectr 10:e01465-e1521. https://doi.org/10.1128/spectrum.01465-21

Barrio I, Arostegui I, Quintana JM, IRYSS-COPD Group (2013) Use of generalised additive models to categorise continuous variables in clinical prediction. BMC Med Res Methodol 13:83. https://doi.org/10.1186/1471-2288-13-83

Bigano A, Goria A, Hamilton JM, Tol RSJ (2005) The effect of climate change and extreme weather events on tourism. SSRN Electron J 2005:673453. https://doi.org/10.2139/ssrn.673453

Budiawan W, Tsuzuki K (2021) Thermal comfort and sleep quality of Indonesian students living in Japan during summer and winter. Buidings 11(8):326. https://doi.org/10.3390/buildings11080326

Canora F, Sdao F (2022) Groundwater vulnerability to pollution assessment. Water 14(14):2205. https://doi.org/10.3390/w14142205

Chaiyat N, Chaongew S, Ondokmai P, Makarkard P (2020) Levelized energy and exergy costings per life cycle assessment of a combined cooling, heating, power and tourism system of the San Kamphaeng hot spring, Thailand. Renew Energ 146:828–842. https://doi.org/10.1016/j.renene.2019.07.028

Chang J, Lin SH-H, Wu L-S (2022) Searching memories of pleasures in local cuisine: how nostalgia and hedonic values affect tourists' behavior at hot spring destinations? Brit Food J 124:493–513. https://doi.org/10.1108/BFJ-04-2021-0387

Channing A (2017) A review of active hot-spring analogues of Rhynie: environments, habitats and ecosystems. Philos Trans R Soc B 373:20160490. https://doi.org/10.1098/rstb.2016.0490

Chen F-H, Hsu T-S, Tzeng G-H (2011) A balanced scorecard approach to establish a performance evaluation and relationship model for hot spring hotels based on a hybrid MCDM model combining DEMATEL and ANP. Int J Hosp Manag 30:908–932. https://doi.org/10.1016/j.ijhm.2011.02.001

Ciobotaru A-M, Andronache I, Dey N, Petralli M, Daneshvar MRM, Wang Q, Radulovic M, Pintilii R-D (2019) Temperature-Humidity Index described by fractal Higuchi Dimension affects tourism activity in the urban environment of Focşani City (Romania). Theor Appl Climatol 136:1009–1019. https://doi.org/10.1007/s00704-018-2501-x

Coccolo S, Kämpf J, Scartezzini J-L, Pearlmutter D (2016) Outdoor human comfort and thermal stress: a comprehensive review on models and standards. Urban Clim 18:33–57. https://doi.org/10.1016/j.uclim.2016.08.004

Cohen P, Potchter O, Matzarakis A (2013) Human thermal perception of Coastal Mediterranean outdoor urban environments. Appl Geogr 37:1–10. https://doi.org/10.1016/j.apgeog.2012.11.001

Craig CA, Feng S (2018) A temporal and spatial analysis of climate change, weather events, and tourism businesses. Tour Manag 67:351–361. https://doi.org/10.1016/j.tourman.2018.02.013

Currie ID, Durban M, Eilers PHC (2006) Generalized linear array models with applications to multidimensional smoothing. J R Stat Soc B 68:259–280. https://doi.org/10.1111/j.1467-9868.2006.00543.x

Dann GMS (1981) Tourist motivation an appraisal. Ann Tour Res 8:187–219. https://doi.org/10.1016/0160-7383(81)90082-7

Datla S, Sharma S (2010) Variation of impact of cold temperature and snowfall and their interaction on traffic volume. Transport Res Rec 2169:107–115. https://doi.org/10.3141/2169-12

Day J, Chin N, Sydnor S, Widhalm M, Shah KU, Dorworth L (2021) Implications of climate change for tourism and outdoor recreation: an Indiana, USA, case study. Clim Change 169:29. https://doi.org/10.1007/s10584-021-03284-w

Demiroglu OC, Hall CM (2020) Geobibliography and bibliometric networks of polar tourism and climate change research. Atmos 11. https://doi.org/10.3390/atmos11050498

Fisichelli NA, Schuurman GW, Monahan WB, Ziesler PS (2015) Protected area tourism in a changing climate: will visitation at US National Parks warm up or overheat? PLoS One 10:e0128226. https://doi.org/10.1371/journal.pone.0128226

Førland EJ, Steen Jacobsen JK, Denstadli JM, Lohmann M, Hanssen-Bauer I, Hygen HO, Tømmervik H (2013) Cool weather tourism under global warming: comparing Arctic summer tourists' weather preferences with regional climate statistics and projections. Tour Manag 36:567–579. https://doi.org/10.1016/j.tourman.2012.09.002

Fotiadis A, Polyzos S, Huan T-CTC (2021) The good, the bad and the ugly on COVID-19 tourism recovery. Ann Tour Res 87:103117. https://doi.org/10.1016/j.annals.2020.103117

Friedrich J, Stahl J, Hoogendoorn G, Fitchett JM (2020) Exploring climate change threats to beach tourism destinations: application of the hazard–activity pairs methodology to South Africa. Weather Clim Soc 12:529–544. https://doi.org/10.1175/WCAS-D-19-0133.1

Giachino C, Truant E, Bonadonna A (2020) Mountain tourism and motivation: millennial students' seasonal preferences. Curr Issues Tour 23:2461–2475. https://doi.org/10.1080/13683500.2019.1653831

Givoni B, Noguchi M, Saaroni H, Pochter O, Yaacov Y, Feller N, Becker S (2003) Outdoor comfort research issues. Energy Build 35:77–86. https://doi.org/10.1016/S0378-7788(02)00082-8

Grossi L, Mussini M (2021) Seasonality in tourist flows: decomposing and testing changes in seasonal concentration. Tourism Manage 84:104289. https://doi.org/10.1016/j.tourman.2021.104289

Guo L, Wang G, Sheng Y, Sun X, Shi Z, Xu Q, Mu W (2020) Temperature governs the distribution of hot spring microbial community in three hydrothermal fields, Eastern Tibetan Plateau Geothermal Belt. Western China. Sci Total Environ 720:137574. https://doi.org/10.1016/j.scitotenv.2020.137574

Gvozdjáková A, Sumbalová Z, Kucharská J, Rausová Z, Kovalčíková E, Takácsová T, Navas P, López-Lluch G, Mojto V, Palacka P (2022) Mountain spa rehabilitation improved health of patients with post-COVID-19 syndrome: pilot study. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-022-22949-2

GWI (2019) Global Wellness Economy Monitor. Global Wellness Institute. https://globalwellnessinstitute.org/industry-research/2018-global-wellness-economy-monitor/. Accessed 3 May 2019

Hewer MJ (2020) Determining the effect of extreme weather events on human participation in recreation and tourism: a case study of the Toronto Zoo. Atmos 11(1):99. https://doi.org/10.3390/atmos11010099

Hsieh L-F, Lin L-H, Lin Y-Y (2008) A service quality measurement architecture for hot spring hotels in Taiwan. Tour Manag 29:429–438. https://doi.org/10.1016/j.tourman.2007.05.009

Huang X, Zhang L, Ding Y (2017) The Baidu Index: uses in predicting tourism flows –a case study of the Forbidden City. Tour Manag 58:301–306. https://doi.org/10.1016/j.tourman.2016.03.015

Huang ZF, Chen B, Guo ZH, Zhang F (2019) Outdoor thermal comfort and adaptive behaviors in a university campus in China's hot summer-cold winter climate region. Build Environ 165:106414. https://doi.org/10.1016/j.buildenv.2019.106414

Hübner A, Gössling S (2012) Tourist perceptions of extreme weather events in Martinique. J Destination Mark Manag 1:47–55. https://doi.org/10.1016/j.jdmm.2012.09.003

Jafari J, Dann GMS (2015) Encyclopedia of tourism. Ann Tour Res 29:885–886. https://doi.org/10.1007/978-3-319-01669-6

Kardeş S (2021) Public interest in spa therapy during the COVID-19 pandemic: analysis of Google Trends data among Turkey. Int J Biometeorol 65:945–950. https://doi.org/10.1007/s00484-021-02077-1

Korpela K, De Bloom J, Sianoja M, Pasanen T, Kinnunen U (2017) Nature at home and at work: naturally good? Links between window views, indoor plants, outdoor activities and employee well-being over one year. Landsc Urban Plan 160:38–47. https://doi.org/10.1016/j.landurbplan.2016.12.005

Lee LSH, Cheung PK, Fung CKW, Jim CY (2020) Improving street walkability: biometeorological assessment of artificial-partial shade structures in summer sunny conditions. Int J Biometeorol 64:547–560. https://doi.org/10.1007/s00484-019-01840-9

Li H, Hu M, Li G (2020) Forecasting tourism demand with multisource big data. Ann Tour Res 83:102912. https://doi.org/10.1016/j.annals.2020.102912

Li R, Chi X (2014) Thermal comfort and tourism climate changes in the Qinghai-Tibet Plateau in the last 50 years. Theor Appl Climatol 117:613–624. https://doi.org/10.1007/s00704-013-1027-5

Lin T-P (2009) Thermal perception, adaptation and attendance in a public square in hot and humid regions. Build Environ 44:2017–2026. https://doi.org/10.1016/j.buildenv.2009.02.004

Liu C, Dou X, Li J, Cai LA (2020) Analyzing government role in rural tourism development: an empirical investigation from China. J Rural Stud 79:177–188. https://doi.org/10.1016/j.jrurstud.2020.08.046

Lozano J, Rey-Maquieira J, Sastre F (2020) An integrated analysis of tourism seasonality in prices and quantities, with an application to the Spanish Hotel Industry. J Travel Res 60:1581–1597. https://doi.org/10.1177/0047287520947807

Maghrifani D, Liu F, Sneddon J (2022) Understanding potential and repeat visitors' travel intentions: the roles of travel motivations, destination image, and visitor image congruity. J Travel Res 61(5):1121–1137. https://doi.org/10.1177/00472875211018508

Marshall NA, Tobin RC, Marshall PA, Gooch M, Hobday AJ (2013) Social vulnerability of marine resource users to extreme weather events. Ecosyst 16:797–809. https://doi.org/10.1007/s10021-013-9651-6

Matthews L, Scott D, Andrey J (2021) Development of a data-driven weather index for beach parks tourism. Int J Biometeorol 65:749–762. https://doi.org/10.1007/s00484-019-01799-7

Matzarakis A (2006) Weather- and climate-related information for tourism. Tour Hosp Plan Dev 3(2):99–115. https://doi.org/10.1080/14790530600938279

Mi C, Chen Y, Cheng C-S, Uwanyirigira JL, Lin C-T (2019) Exploring the determinants of hot spring tourism customer satisfaction: causal relationships analysis using ISM. Sustain 11:2613. https://doi.org/10.3390/su11092613

Min C-k, Roh T-s, Bak S (2016) Growth effects of leisure tourism and the level of economic development. Appl Econ 48:7–17. https://doi.org/10.1080/00036846.2015.1073838

Min J-y, Choi Y-S, Lee H-S, Lee S, Min K-b (2021) Increased cold injuries and the effect of body mass index in patients with peripheral vascular disease. BMC Public Health 21:294. https://doi.org/10.1186/s12889-020-09789-w

Moral-Carcedo J, Vicéns-Otero J (2005) Modelling the non-linear response of Spanish electricity demand to temperature variations. Energ Econ 27(3):477–494. https://doi.org/10.1016/j.eneco.2005.01.003

R-Toubes D, Araújo-Vila N, Fraiz-Brea JA (2020) Influence of weather on the behaviour of tourists in a beach destination. Atmos 11:121. https://doi.org/10.3390/atmos11010121

Rather RA, Hollebeek LD, Rasoolimanesh SM (2022) First-time versus repeat tourism customer engagement, experience, and value cocreation: an empirical investigation. J Travel Res 61(3):549–564. https://doi.org/10.1177/0047287521997572

Reiss R (2006) Temporal trends and weekend–weekday differences for benzene and 1,3-butadiene in Houston. Texas Atmos Environ 40(25):4711–4724. https://doi.org/10.1016/j.atmosenv.2006.04.023

Saenz-de-Miera O, Rosselló J (2014) Modeling tourism impacts on air pollution: the case study of PM10 in Mallorca. Tour Manag 40:273–281. https://doi.org/10.1016/j.tourman.2013.06.012

Scott D, Gössling S (2022) A review of research into tourism and climate change - launching the annals of tourism research curated collection on tourism and climate change. Ann Tour Res 95:103409. https://doi.org/10.1016/j.annals.2022.103409

Serquet G, Rebetez M (2011) Relationship between tourism demand in the Swiss Alps and hot summer air temperatures associated with climate change. Clim Change 108:291–300. https://doi.org/10.1007/s10584-010-0012-6

Sibitane ZE, Dube K, Lekaota L (2022) Global warming and its implications on nature tourism at Phinda Private Game Reserve, South Africa. Int J Environ Res Public Health 19(9):5487. https://doi.org/10.3390/ijerph19095487

Sottini VA, Barbierato E, Bernetti I, Capecchi I (2021) Impact of climate change on wine tourism: an approach through social media data. Sustain 13:7489. https://doi.org/10.3390/su13137489

Sun SL, Wei YJ, Tsui KL, Wang SY (2019) Forecasting tourist arrivals with machine learning and internet search index. Tour Manag 70:1–10. https://doi.org/10.1016/j.tourman.2018.07.010

Takeshita RSC, Bercovitch FB, Kinoshita K, Huffman MA (2018) Beneficial effect of hot spring bathing on stress levels in Japanese macaques. Primates 59:215–225. https://doi.org/10.1007/s10329-018-0655-x

Tan WK (2017) Repeat visitation: a study from the perspective of leisure constraint, tourist experience, destination images, and experiential familiarity. J Destin Mark Manage 6(3):233–242. https://doi.org/10.1016/j.jdmm.2016.04.003

Tervo K (2008) The operational and regional vulnerability of winter tourism to climate variability and change: the case of the Finnish nature-based tourism entrepreneurs. Scand J Hosp Tour 8:317–332. https://doi.org/10.1080/15022250802553696

Theofilatos A, Yannis G (2014) A review of the effect of traffic and weather characteristics on road safety. Accident Anal Prev 72:244–256. https://doi.org/10.1016/j.aap.2014.06.017

Tiwari AK, Nasreen S, Iqbal Z (2021) Nexus between tourism and environmental pollution in South Asia: a comparative analysis using time-varying and non-parametric techniques. Curr Issues Tour 24:2996–3020. https://doi.org/10.1080/13683500.2020.1862070

Valjarević A, Vukoičić D, Valjarević D (2017) Evaluation of the tourist potential and natural attractivity of the Lukovska Spa. Tour Manag Perspect 22:7–16. https://doi.org/10.1016/j.tmp.2016.12.004

Vatsa P (2021) Seasonality and cycles in tourism demand—redux. Ann Tour Res 90:103105. https://doi.org/10.1016/j.annals.2020.103105

Wang L, Fang B, Law R (2018) Effect of air quality in the place of origin on outbound tourism demand: disposable income as a moderator. Tour Manag 68:152–161. https://doi.org/10.1016/j.tourman.2018.03.007

Wang L, Zhou X, Lu M, Cui Z (2020) Impacts of haze weather on tourist arrivals and destination preference: analysis based on Baidu Index of 73 scenic spots in Beijing. China. J Clean Prod 273:122887. https://doi.org/10.1016/j.jclepro.2020.122887

Wang W-C, Lin C-H (2021) A model for sustainable tourism development of hot spring destinations following poverty alleviation: understanding the tourists' perspective. Sustain 13(17):9856. https://doi.org/10.3390/su13179856

WHO (2018) COP24 Special report: health and climate change, 2018. World Health Organization. https://apps.who.int/iris/bitstream/handle/10665/276405/9786057496713-tur.pdf. Accessed 14 Dec 2018

Wilkins E, Urioste-Stone S, Weiskittel A, Gabe T (2017) Effects of weather conditions on tourism spending: implications for future trends under climate change. J Travel Res 57(8):1–12. https://doi.org/10.1177/0047287517728591

Wood SN (2006) Generalized additive models: an introduction with R. CRC Press, New York

Wu Y, Zhou X, Wang M, Zhuo L, Xu H, Liu Y (2021) Comparison of hydrogeological characteristics and genesis of the Xiaguan Hot Spring and the Butterfly Spring in Yunnan of China. J Hydrol 593:125922. https://doi.org/10.1016/j.jhydrol.2020.125922

Xie G, Qian Y, Wang S (2021) Forecasting Chinese cruise tourism demand with big data: an optimized machine learning approach. Tour Manag 82:104208. https://doi.org/10.1016/j.tourman.2020.104208

Xu X, Rioux TP, Gonzalez J, Hansen EO, Castellani JW, Santee WR, Karis AJ, Potter AW (2021) A digital tool for prevention and management of cold weather injuries—Cold Weather Ensemble Decision Aid (CoWEDA). Int J Biometeorol 65:1415–1426. https://doi.org/10.1007/s00484-021-02113-0

Yan R, Woith H, Wang R, Wang G (2017) Decadal radon cycles in a hot spring. Sci Rep 7:12120. https://doi.org/10.1038/s41598-017-12441-0

Yang X, Pan B, Evans JA, Lv B (2015) Forecasting Chinese tourist volume with search engine data. Tour Manag 46:386–397. https://doi.org/10.1016/j.tourman.2014.07.019

Yao L, Ma R, Wang H (2021) Baidu index-based forecast of daily tourist arrivals through rescaled range analysis, support vector regression, and autoregressive integrated moving average. Alexandria Eng J 60:365–372. https://doi.org/10.1016/j.aej.2020.08.037

Yin Q, Cao Y, Sun C (2021) Research on outdoor thermal comfort of high-density urban center in severe cold area. Build Environ 200:107938. https://doi.org/10.1016/j.buildenv.2021.107938

Yoon H (2019) Effects of particulate matter (PM10) on tourism sales revenue: a generalized additive modeling approach. Tour Manag 74:358–369. https://doi.org/10.1016/j.tourman.2019.04.008

Yu Q, Wang Y (2020) Effects of hot spring tourism on human health. Des Eng 1:11–19. https://doi.org/10.17762/de.vi.966

Zhang D, Guo Y, Rutherford S, Qi C, Wang X, Wang P, Zheng Z, Xu Q, Li X (2019) The relationship between meteorological factors and mumps based on Boosted regression tree model. Sci Total Environ 695:133758. https://doi.org/10.1016/j.scitotenv.2019.133758

Zhang J, Yu ZL, Miao CH, Li YT, Qiao S (2022) Cultural tourism weakens seasonality: empirical analysis of Chinese tourism cities. Land 11(2):308. https://doi.org/10.3390/land11020308

Zhang W, Yan K, Shen D (2021) Can the Baidu Index predict realized volatility in the Chinese stock market? Financ Innovation 7:7. https://doi.org/10.1186/s40854-020-00216-y