

Article

A Comprehensive Evaluation Model for Local Summer Climate Suitability under Global Warming: A Case Study in Zhejiang Province

Kuo Wang ^{1,2,†}, Zhihang Xu ^{3,†}, Gaofeng Fan ^{1,†}, Dawei Gao ^{1,†}, Changjie Liu ^{1,†}, Zhenyan Yu ^{1,†}, Xia Yao ^{4,†} and Zhengquan Li ^{1,*,†}

¹ Zhejiang Climate Center, Meteorological Bureau of Zhejiang Province, Hangzhou 310051, China; wangkuo_climate@163.com (K.W.); fangaofengcn@163.com (G.F.); davidgao82@163.com (D.G.); jianfei2009@163.com (C.L.); yuzhenyan@126.com (Z.Y.)

² State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources, Hangzhou 310012, China

³ Taizhou Meteorological Observatory, Taizhou Meteorological Bureau, Taizhou 318001, China; xuzhh17@163.com

⁴ Beilun Meteorological Bureau, Ningbo 318001, China; yaoxiayiyi@163.com

* Correspondence: lzq110119@163.com

† These the authors contributed equally to this paper.

Abstract: In the context of global warming, how to measure summer climate suitability at a local scale is important for meteorological services. Considering meteorological and ecological conditions, body comfort, and the atmospheric environment, an assessment method for summer climate suitability for Zhejiang Province is proposed. In this paper, a summer suitable index (SSI) for Zhejiang is calculated, including four secondary indices: a summer cool index (SCI), a comfort days index (CDI), a good air days index (GADI) and a vegetation cover index (VCI). Using a local evaluation criterion, summer climate suitable areas are distinguished objectively according to the SSI. The results show that especially suitable regions account for 4.97% of Zhejiang Province, very suitable regions account for 22.2%, suitable regions account for 39.58%, and general regions account for 33.25%. The summer climate suitable areas are located mainly in high mountains and hills and coastal island areas while plain areas cannot be considered a suitable destination for summer tourism. By comparison and discussion, the SSI is demonstrated to capture summer climate suitability well. In contrast to a fixed evaluation index, benchmark values obtained for the SSI depend on the local climate and the index is straightforward to apply.

Keywords: summer climate suitability; local evaluating indicator; Zhejiang Province; global warming



Citation: Wang, K.; Xu, Z.; Fan, G.; Gao, D.; Liu, C.; Yu, Z.; Yao, X.; Li, Z. A Comprehensive Evaluation Model for Local Summer Climate Suitability under Global Warming: A Case Study in Zhejiang Province. *Atmosphere* **2022**, *13*, 1075. <https://doi.org/10.3390/atmos13071075>

Academic Editor: Fei Ji

Received: 7 June 2022

Accepted: 6 July 2022

Published: 7 July 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

With global warming, high impact extreme weather and climate events are now happening frequently in China [1–3]. Extreme heat waves have become one of the main meteorological events affecting people's work and life [4,5]. High temperatures can cause sweating, increase electrolyte metabolism and affect brain activity. They can also cause a variety of heat-related conditions, such as heat stroke, heat sickness, heat spasm, cardio-cerebrovascular disease, etc. [6,7]. Thus, in hot summer, it is necessary to find cool and suitable places as outdoor travel destinations. A suitable summer resort can ensure that tourists are not only healthy but are also happy. The tourism economy and summer-avoiding economy have gradually become of major concern for urban development, attracting significant attention from society and government.

Global warming is one of the most challenging global issues [8–10]. However, because of the multiple scales of climate change effects, climates and natural systems at

different spatiotemporal scales show different change characteristics [11–13]. A key scientific issue in ecometeorological research is how to objectively evaluate the suitability of summer climate as a basis for recommending suitable summer tourism city and scenic spot destinations [14,15]. Wu and Ge [16] analyzed Hainan's climate comfort and its correlation with tourist flow applying the comfort index of W. H. Terjung. It was found that temperature-dominated climate comfort was the main factor influencing Hainan's tourist flow and tourist decisions. Lin [17] used the tourism climate index (TCI), physiological equivalent temperature (PET) and the climate tourism information scheme (CTIS) to analyze the climate comfort of 25 summer cities in northern China between 1980 and 2009 and simulated the maximum metabolic rate of the human body in summer cities. Hou et al. [18] established a summer weather index based on climatic analysis results for the daily mean temperature, maximum temperature, precipitation, sunshine duration and relative humidity of 14 summer tourism scenic spots of Liaoning Province from 2006 to 2015, dividing the conditions into four levels to provide a comprehensive evaluation of the suitability of summer tourism in Liaoning Province.

The climate of Zhejiang, located in east China, is controlled by subtropical monsoon. The summer of Zhejiang begins from late May or early June. The early summer is mainly characterized as Meiyu season, while the midsummer is hot and dry [19–21]. With global warming and urbanization, annual summer high temperature days and maximum temperature have shown an increasing trend according to data from most meteorological stations in Zhejiang [22]. Heat waves have occurred frequently in recent years. For example, a very serious heat wave affected Zhejiang in the summer of 2013; the recorded average temperature, high temperature days and extreme maximum temperature all broke records kept since 1951. The highest temperature recorded during the 2013 heat wave was 44.1 °C in Shaoxing city. Previous studies have shown that extreme weather and climate events will become more and more serious in the context of global warming, particularly heat waves and rainstorms [23–25]. Hence, both society and government are paying attention to the need for summer meteorological services in Zhejiang Province.

Although the summer climate has been analyzed and evaluated in some regions of China [26–28], the evaluation indices used cannot be applied directly to Zhejiang because of the great climate differences at different spatiotemporal scales. There has been limited study of the Zhejiang summer climate, and its characteristics and variation, such as high temperature duration, high temperature intensity and summer body comfort require to be clarified. It is therefore important that more scientific research, including evaluation of suitable summer climate conditions, is undertaken to provide a reference basis and guidance for further development of the summer tourism industry. Based on previous research, this paper reports the development of a comprehensive evaluation system for summer high temperature persistence, high temperature intensity, body comfort and other climatic elements, and estimates the distribution of summer climate suitability in Zhejiang Province.

2. Data and Methodology

A multi-source grid product was obtained from the China Meteorological Administration CMA Land Data Assimilation System (CLIDAS), published by the National Meteorological Information Center (NMIC) of CMA. The time span was 2008–2011, the time resolution was hourly and the spatial resolution was $0.0625^\circ \times 0.0625^\circ$ [29]. In addition, air quality data were obtained from the Department of Ecological Environment of Zhejiang Province, and vegetation coverage data from moderate resolution imaging spectroradiometer (MODIS) remote sensing with a spatial resolution of $250\text{ m} \times 250\text{ m}$; the data formats were unified using Kriging interpolation [30]. In this paper, the summer was taken to include only July and August (62 days), because June is a rainy month and is not hot in Zhejiang [31]. In meteorological and touristic studies, calculation of a meteorological index is a common way to estimate the climate suitability [32–34]. In this paper, four

elements which summer tourists care most about were selected. According to Equation (1), the summer suitable index was calculated as follows:

$$SSI = SCI \times W_1 + CDI \times W_2 + GADI \times W_3 + VCI \times W_4 \quad (1)$$

where SSI is the summer suitable index, SCI is the summer coolness index, CDI is the comfort days index, GADI is the good air days index, and VCI is the vegetation coverage index. A total of 20 meteorological experts from different cities were invited to estimate the local summer climate suitability. Weights were set according to the importance of each element to summer resorts and were comprehensively scored by these experts. W_1 , W_2 , W_3 , and W_4 represent the weight scores for each index, respectively (Table 1).

Table 1. Weight scores of summer climate suitability index.

Index	Element	Weight Scores
SCI	High temperature days High temperature hours Maximum temperature	50 (W_1)
CDI	Air temperature Relative humidity Wind speed	30 (W_2)
GADI	AQI grade days	10 (W_3)
VCI	Vegetation coverage	10 (W_4)
Total		100

The details of calculation for each index are as follows.

1. Summer coolness index (SCI)

$$SCI = 1.34 - [(T_{dr} + T_{hr})/2 + T_{mr}]/2 \quad (2)$$

where $T_{dr} = T_{days}/T_{dm}$, $T_{hr} = T_{hours}/T_{hm}$, and $T_{mr} = T_{max}/T_{mm}$. T_{days} is the days of daily temperature exceeding 30 °C, T_{hours} is the hours of hourly temperature exceeding 35 °C, T_{max} is the maximum temperature. T_{dm} , T_{hm} and T_{mm} are the benchmark values for Zhejiang, representing days of daily temperature exceeding 30 °C, hours of hourly temperature exceeding 35 °C, and the maximum temperature in the Zhejiang area, with values of 49, 286 and 42.2, respectively. The benchmark values are set based on the characteristics of local climate, which enables the SSI to be easily applied elsewhere.

2. Comfort days index (CDI)

$$CDI = (D_{BCMI4} \times \beta_1 + D_{BCMI5} \times \beta_2 + D_{BCMI6} \times \beta_3)/D_{all} \quad (3)$$

$$BCMI = (1.8t + 32) - 0.55 \times (1 - rh) \times (1.8t - 26) - 3.2\sqrt{v} \quad (4)$$

where D_{BCMI4} , D_{BCMI5} , and D_{BCMI6} are the days where the body comfort meteorology index (BCMI) reaches 4, 5 and 6 grads, respectively. D_{all} is the summer total days and is taken to be 62 in this paper. β_1 , β_2 and β_3 are the weight coefficients for D_{BCMI4} , D_{BCMI5} , and D_{BCMI6} , respectively. β_1 and β_3 are 0.8, and β_2 is 1.0. In Equation (4), t is the air temperature, rh is the relative humidity, and v is the wind speed. The details of the levels are shown in Table 2.

3. Good air days index (GADI)

$$GADI = (D_{AQIY} \times W_1 + D_{AQIL} \times W_2)/D_{all} \quad (5)$$

where D_{AQIY} and D_{AQIL} are the days the air quality index (AQI) reached excellent and good grades, respectively [35]. D_{all} is the total days and is defined as 62 in this paper. W_1 and W_2 are the weight coefficients for D_{AQIY} and D_{AQIL} , being 1.0 and 0.8, respectively.

4. Vegetation coverage index (VCI)

The VCI refers to the percentage of vertical projection of the vegetation canopy in the cross-sectional area of the statistical area. It is an important index for measuring the regional ecological environment. This study calculated VCI according to the pixel dichotomy method [36].

$$VCI = \frac{NDVI - NDVI_{soil}}{NDVI_{vegetation} - NDVI_{soil}} \quad (6)$$

where NDVI refers to the normalized difference vegetation index and data from the MODIS monthly synthetic products; $NDVI_{soil}$ represents the value at which the pixel is pure bare soil, and $NDVI_{vegetation}$ represents the value at which the pixel is pure vegetation. According to the characteristics of vegetation in China, the $NDVI_{soil}$ and the $NDVI_{vegetation}$ values in this study were 0.05 and 0.95, respectively.

Table 2. Levels of body comfort meteorology index (BCMI).

Interval	Grades	Weight	Coefficient
BCMI < 25	1		
25 ≤ BCMI < 38	2		
38 ≤ BCMI < 50	3		
50 ≤ BCMI < 58	4	β_1	0.8
58 ≤ BCMI < 70	5	β_2	1.0
70 ≤ BCMI < 75	6	β_3	0.8
75 ≤ BCMI < 79	7		
79 ≤ BCMI < 85	8		
85 ≤ BCMI	9		

3. Results

3.1. SCI Pattern in Zhejiang Province

More than 25 high temperature days were recorded in northern and central Zhejiang, corresponding to the Hangjiahu Plain and the Jinqu Basin. Fewer than 10 high temperature days were mainly recorded in northwest Zhejiang and southern Zhejiang, where the Tianmu Mountain, Yandang Mountain and other mountain areas are located. High temperatures ($\geq 35^\circ\text{C}$) of more than 140 h in Zhejiang Province occurred in northern Zhejiang and southern central Zhejiang, with the observed range being wider than for the high temperature days. Daily maximum temperatures over 39°C were mainly distributed in the north of Zhejiang Province and the south of central Zhejiang Province.

Based on the high temperature days, high temperature hours and daily maximum temperature, the SCI was calculated according to Equation (2). Overall, south Zhejiang was cooler than north Zhejiang, and the eastern coast was relatively cooler (Figure 1), which is consistent with the distribution of high temperature days, high temperature hours and maximum temperature. The SCI was over 0.75 in the high mountains and coastal areas, and below 0.40 in the Hangjiahu Plain and the Jinqu Plain.

3.2. CDI Pattern in Zhejiang Province

The comfort days index (CDI) is an important index of summer climate suitability; the comfort of the human body is closely related to the local temperature, humidity and wind conditions. Based on meteorological observation data, the daily average temperature, relative humidity and wind speed in Zhejiang for July and August from 2008 to 2017 was analyzed. Mean temperatures of more than 39°C were mainly distributed in northern Zhejiang and southern central Zhejiang, similar to the distribution of high temperature days in Zhejiang. The areas with average relative humidity over 80% were mainly distributed in the mountainous areas of northwest Zhejiang and the east coast. Areas of average relative humidity below 80% were mainly distributed in the central region of Zhejiang province. Due to differences in the underlying surface, the sea surface wind speed was

significantly higher. The regions with an average wind speed of more than 1.0 m/s were mainly distributed in the coastal area of eastern Zhejiang, while the regions where the average wind speed was lower than 0.5 m/s were mainly distributed in the southwestern mountainous area.

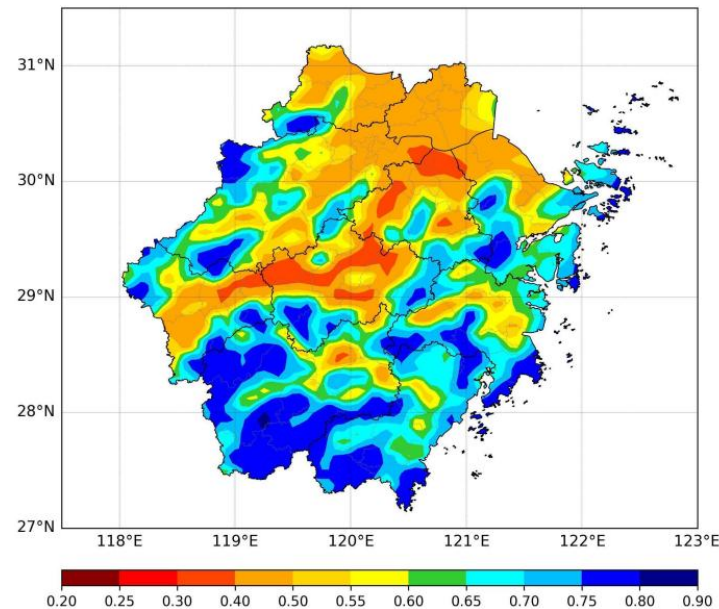


Figure 1. Distribution of SCI in Zhejiang Province.

According to Equations (3) and (4), based on the above indices, CDI was calculated and analyzed as shown in Figure 2. Recorded CDI values were relatively higher in the northwest and southwest of Zhejiang. In other regions, such as the central and northern areas and the southeast coastal region, due to higher average temperature, lower relative humidity and faster wind speed, comfortable days, corresponding to BCMI index grades 4–6, were less. In general, the high-altitude area of Zhejiang was more comfortable, with a CDI value of more than 0.5. Other regions were relatively low.

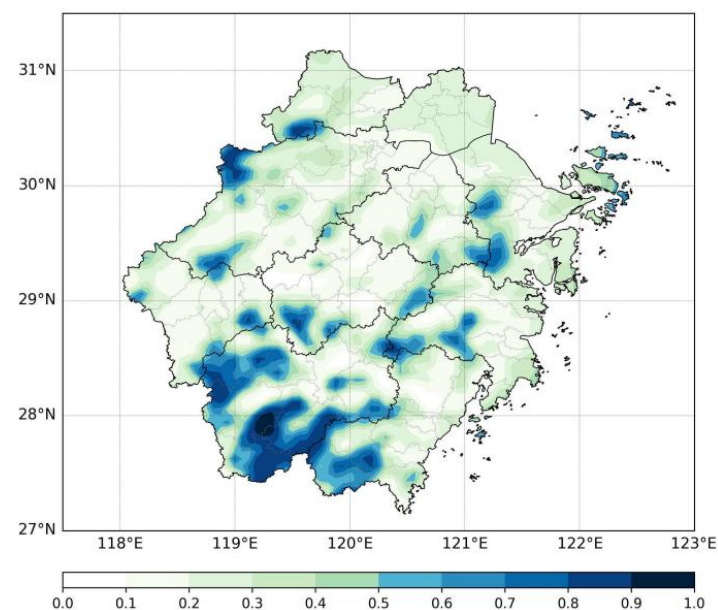


Figure 2. Distribution of CDI in Zhejiang Province.

3.3. GADI Pattern in Zhejiang Province

To determine the climate distribution of the GADI in summer, we counted the days the air quality index (AQI) reached an excellent or good grade for July and August in Zhejiang, and then calculated the GADI according to the weight of the different air grades, applying Equation (5). Overall, the southern Zhejiang area had better air quality than the northern area; in northern Zhejiang, the recorded GADI values near coastal and riverine areas were higher than for the inland areas. Comparing areas with different elevations, the GADI values at higher elevations were higher than for the plain areas. The regions with fresher air were located in the mountainous areas of southern Zhejiang and the coastal areas of Taizhou, with GADI values above 9. Recorded GADI values in northern Zhejiang were relatively lower, especially in Shaoxing.

3.4. VCI Pattern in Zhejiang Province

The spatial distribution of vegetation coverage in Zhejiang province was obtained using remote sensing satellite data. Most areas had more than 50% vegetation coverage, though some plain and coastal areas had a vegetation coverage of less than 50%. On this basis, we used GIS to calculate the average vegetation coverage of villages in Zhejiang province according to Equation (6), and normalized the VCI of Zhejiang province in summer, as shown in Figure 3.

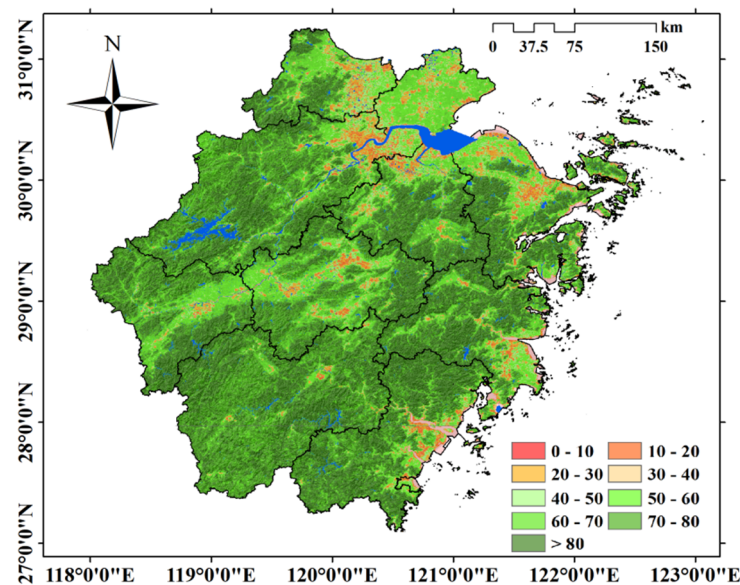


Figure 3. Distribution of VCI in Zhejiang Province (Unit: %).

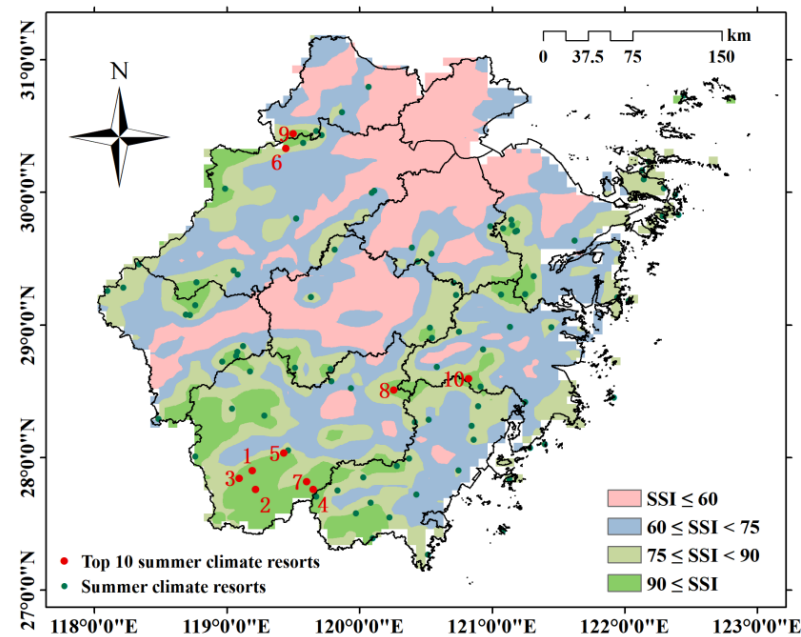
3.5. SSI Pattern in Zhejiang Province

Based on the meteorological observation data, satellite remote sensing data and geographic information data, a comprehensive evaluation model for the climate conditions of summer was established as Equation (1), and the distribution of SSI in Zhejiang Province was drawn according to a comprehensive scoring method, as shown in Figure 4.

The especially suitable regions ($90 \leq \text{SSI}$) accounted for 4.97% of Zhejiang province, the very suitable regions ($75 \leq \text{SSI} < 90$) accounted for 22.2%, the suitable regions ($60 \leq \text{SSI} < 75$) accounted for 39.58%, and the general regions ($\text{SSI} < 60$) accounted for 33.25%. The summer suitable climate areas of Zhejiang province were mainly located in the high mountains and hills and the coastal island areas, while for plain areas, suitable summer climate areas were not common.

Table 3. Top 10 summer climate resorts in Zhejiang Province.

City	District	Name of the Resort	SSI Score	Rank
Lishui	Longquan	Longquan Mountain Tourist Area	96.2	1
Lishui	Qingyuan	Baishanzu National Nature Reserve	94.5	2
Lishui	Longquan	Pingtian Village	93.8	3
Lishui	Jingning	Yunshangtianchi Scenic Spot	92.5	4
Lishui	Yunhe	Huangjiashe Village	90.6	5
Hangzhou	Lin'an	Tianmu Mountain Scenic Area	90.1	6
Lishui	Jingning	Yunzhongdaji Scenic Spot	90.1	7
Lishui	Jinyun	Qiancun Village	89.9	8
Huzhou	Anji	North Zhejiang Grand Canyon	88.5	9
Taizhou	Huangyan	Dasiji Scenic Spot	88.2	10

**Figure 4.** Distribution of SSI in Zhejiang Province. Green dots are the summer climate resorts, red dots are the top 10 summer climate resorts and red number is the rank corresponding to Table 3.

Based on climate regionalization, the summer climate resorts were evaluated and ranked using the SSI values from 2000 meteorological observation stations in Zhejiang province. According to the analysis, the summer climate resorts in Zhejiang province were mainly located in the mountains and coastal island areas (Figure 4), which is consistent with the evaluation results of existing studies and reports by the mass media. The number of summer climate resorts varied greatly among different cities, being closely related to the richness of the local climate resources.

4. Discussion and Conclusions

In the context of climate change, the responses to global warming are inconsistent across different regions. Huang et al. [37] found that surface air temperature trends were particularly enhanced in the boreal cold season over semi-arid regions between 1901 and 2009, with a drier and warmer trend in semi-arid regions. Local climatic conditions were also affected by the atmospheric circulation. For example, changes in the intensity of the Hadley circulation affected the vertical transport of water vapor in tropical regions, influencing water cycle processes and the distribution of precipitation [38]. The evolution trends of the Hadley circulation have obvious regional and seasonal characteristics, and are one of the reasons for regional climate differences [39–41]. In addition, the surrounding geographical environment and human social activities also play an important role in regional

climate conditions; therefore, assessment of climate suitability requires consideration of local conditions.

In the past, limited by the regional area, land and sea differences and the topographic factors of Zhejiang Province, previous indicators have not been suitable for the evaluation of the climate suitability of summer resorts. Therefore, it was necessary to comprehensively consider the issues and to develop a set of indicators suitable for Zhejiang Province. In this regard, by analysis of the SCI, CDI, GADI and VCI, and considering the situation of Zhejiang Province, we proposed the SSI to evaluate the climate suitability of summer vacation destinations according to local indicators. In contrast to fixed evaluation indices, the benchmark values for the SSI depend on local climate, and it can easily be applied in different locations.

However, it should be noted that global warming is becoming more and more intense—the warming trend in China has shown no signs of abating in recent years. Hot summers will become even more frequent in the future [42]. Several regions in China show different temperature trends. From 1901 to 2015, the homogenized annual mean surface air temperature exhibited a range of trends: between 1.1 °C and 4.0 °C/century in northeastern China, between 0.4 °C and 1.9 °C/century in southeastern China, and between 1.4 °C and 3.7 °C/century in western China to the west of 105° E [43]. Cheng et al. [44] found that, in eastern China, the four temperature extremes (warm days, cold days, warm nights and cold nights) for winter have decreased almost everywhere, while those for summer have decreased in the north but increased in the south. Therefore, under global warming, whether the summer assessment system for particular regions needs to be updated synchronously to adapt to the background of global warming needs to be considered. It is necessary to check the summer climate resorts in Zhejiang Province at regular intervals of several years.

Finally, the original intention of the evaluation and recommendation of summer resorts was to provide information to support people when choosing summer resorts, and to make it more straightforward for them to be able to identify travel destinations. At its present stage of development, the evaluation model uses coolness and comfort as the main scoring criteria, and can capture summer climate suitability well. With continuous improvement in living standards, the requirements for a suitable ecological environment and air quality will also increase, so the weighting of relevant scoring items may become more important in the evaluation and recommendation of summer resorts in the future. In addition, due to the limitations of observation and data processing, whether it will be necessary to add new evaluation indicators to make the evaluation more systematic and comprehensive remains to be tested.

Author Contributions: Conceptualization, K.W. and Z.L.; methodology, K.W.; software, D.G.; validation, G.F. and Z.L.; formal analysis, Z.Y.; investigation, X.Y.; data curation, C.L.; writing—original draft preparation, K.W. and Z.X.; writing—review and editing, K.W.; visualization, G.F.; supervision, Z.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Key R&D Program of Zhejiang Province (2021C02036), Policy Research Project of Meteorological Development and Planning Institute, China Meteorological Administration (ZCYJ20220010), the Public Welfare Technology Research Projects of Zhejiang Province (LGF22D050001), Hangzhou Agricultural and Social Development Scientific Research Project (20201203B155), the National Natural Science Foundation of China (41905053), the Fund for Meteorological Science and Technology of Zhejiang Province, China (2021ZD08, 2019YB03), and the open fund of the State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, Ministry of Natural Resources (QNHX2205).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

- Huang, J.; Yu, H.; Guan, X.; Wang, G.; Guo, R. Accelerated dryland expansion under climate change. *Nat. Clim. Chang.* **2016**, *6*, 166–171. [\[CrossRef\]](#)
- Feng, G.; Gong, Z.; Zhi, R. Latest advances in climate change detection techniques. *J. Meteorol. Res.* **2010**, *24*, 1–16. [\[CrossRef\]](#)
- Wang, K.; Zhang, H.; Fan, G.; Li, Z.; Yu, Z.; Liu, P. Simulated variation characteristics of ocean CO₂ uptake, surface temperature and acidification in Zhejiang Province, China. *Front. Phys.* **2021**, *9*, 718968. [\[CrossRef\]](#)
- Meinshausen, M.; Meinshausen, N.; Hare, W.; Raper, S.C.B.; Frieler, K.; Knutti, R.; Frame, D.J.; Allen, M.R. Greenhouse-gas emission targets for limiting global warming to 2 °C. *Nature* **2009**, *458*, 1158–1162. [\[CrossRef\]](#)
- Ding, T.; Ke, Z. Characteristics and changes of regional wet and dry heat wave events in China during 1960–2013. *Theor. Appl. Climatol.* **2015**, *122*, 651–665. [\[CrossRef\]](#)
- Kovats, R.S.; Kristie, A.L.E. Heatwaves and public health in Europe. *Eur. J. Public Health* **2007**, *16*, 592–599. [\[CrossRef\]](#)
- Tong, S.; Fitzgerald, G.; Wang, X.; Aitken, P.; Tippet, V.; Chen, D.; Wang, X.; Guo, Y. Exploration of the health risk-based definition for heatwave: A multi-city study. *Environ. Res.* **2015**, *142*, 696–702. [\[CrossRef\]](#)
- Sun, G.; Wang, C.; Chang, L.; Wu, Y.; Li, L.; Jin, Z. Effects of feedback regulation on vegetation patterns in semi-arid environments. *Appl. Math. Model* **2018**, *61*, 200–215. [\[CrossRef\]](#)
- Ji, F.; Wu, Z.; Huang, J.; Chassignet, E. Evolution of land surface air temperature trend. *Nat. Clim. Chang.* **2014**, *4*, 462–466. [\[CrossRef\]](#)
- Zhang, H.; Wang, K. Simulated CO₂-induced ocean acidification for ocean in the East China: Historical conditions since preindustrial time and future scenarios. *Sci. Rep.* **2019**, *9*, 18559. [\[CrossRef\]](#)
- Stocker, T.F.; Schmittner, A. Influence of CO₂ emission rates on the stability of the thermohaline circulation. *Nature* **1997**, *388*, 862–865. [\[CrossRef\]](#)
- Wang, N.; Zhou, K.; Wang, K.; Feng, T.; Zhang, Y.; Song, C. Climate change characteristics of coastal wind energy resources in Zhejiang Province based on ERA-Interim data. *Front. Phys.* **2021**, *9*, 720533. [\[CrossRef\]](#)
- Wang, K.; Feng, G.; Zeng, Y.; Wang, X. Analysis of stable components in extended-range forecast for the coming 10–30 days in winter 2010 and 2011. *Chin. Phys. B* **2013**, *22*, 129202. [\[CrossRef\]](#)
- Noome, K.; Fitchett, J.M. An assessment of the climatic suitability of Afriski Mountain Resort for outdoor tourism using the Tourism Climate Index (TCI). *J. Mt. Sci.* **2019**, *16*, 2453–2469. [\[CrossRef\]](#)
- Yan, H.; Bi, H.; Li, R.; Eldridge, R.; Wu, Z.; Li, Y.; Simpson, J. Assessing climatic suitability of *Pinus radiata* (D. Don) for summer rainfall environment of southwest China. *Forest. Ecol. Manag.* **2006**, *234*, 199–208. [\[CrossRef\]](#)
- Wu, P.; Ge, Q. An analysis of annual variation of tourist flows and climate change in Hainan Province. *Geogr. Res.* **2009**, *28*, 1078–1084. [\[CrossRef\]](#)
- Lin, W. THE study of Impact of Climate Comfort on Tourism Activities. Master's Thesis, Shanghai Normal University, Shanghai, China, 2017.
- Hou, Y.; Xi, T.; Xu, F.; Zhang, R.; Zhao, M.; Guan, J. Climate condition analysis and meteorological index study of summer tourism in Liaoning. *Meteor. Environ. Sci.* **2018**, *41*, 34–40. [\[CrossRef\]](#)
- Wang, B.; Lee, J.-Y.; Xiang, B. Asian summer monsoon rainfall predictability: A predictable mode analysis. *Clim. Dyn.* **2015**, *44*, 61–74. [\[CrossRef\]](#)
- Ding, Y.; Liu, Y.; Song, Y.; Zhang, J. From MONEX to the global monsoon: A review of monsoon system research. *Adv. Atmos. Sci.* **2015**, *32*, 10–31. [\[CrossRef\]](#)
- Feng, G.; Sun, S.; Zhao, J.; Zheng, Z. Analysis of stable components for extended-range (10–30 days) weather forecast: A case study of continuous overcast-rainy process in early 2009 over the mid-lower reaches of the Yangtze River. *Sci. China Earth Sci.* **2013**, *56*, 1576–1587. [\[CrossRef\]](#)
- Yang, X.; Hou, Y.; Cheng, B. Observed surface warming induced by urbanization in east China. *J. Geophys. Res.* **2011**, *116*, D14113. [\[CrossRef\]](#)
- Trenberth, K.E. Changes in precipitation with climate change. *Clim. Res.* **2010**, *47*, 123–138. [\[CrossRef\]](#)
- Della-Marta, P.M.; Haylock, M.R.; Luterbacher, J.; Wanner, H. Doubled length of western European summer heat waves since 1880. *J. Geophys. Res.* **2007**, *112*, D15103. [\[CrossRef\]](#)
- Shi, N.; Wang, Y.; Wang, X.; Tian, P. Interdecadal Variations in the Frequency of Persistent Hot Events in Boreal Summer over Midlatitude Eurasia. *J. Clim.* **2019**, *32*, 5161–5177. [\[CrossRef\]](#)
- Zhai, P.; Pan, X. Trends in temperature extremes during 1951–1999 in China. *Geophys. Res. Lett.* **2003**, *30*, 169–172. [\[CrossRef\]](#)
- Zhang, Q.; Xu, C.-Y.; Zhang, Z.; Ren, G.; Chen, Y. Climate change or variability? The case of Yellow river as indicated by extreme maximum and minimum air temperature during 1960–2004. *Theor. Appl. Climatol.* **2008**, *93*, 35–43. [\[CrossRef\]](#)
- Li, S.; Hou, W.; Feng, G. Atmospheric Circulation Patterns over East Asia and Their Connection with Summer Precipitation and Surface Air Temperature in Eastern China during 1961–2013. *J. Meteorol. Res.* **2008**, *32*, 203–218. [\[CrossRef\]](#)
- Shi, C.; Pan, Y.; Gu, J.; Xu, B.; Han, S.; Zhu, Z.; Zhang, L.; Sun, S.; Jiang, Z. A review of multi-source meteorological data fusion products. *Acta Meteorol. Sin.* **2019**, *77*, 774–783. [\[CrossRef\]](#)
- Rousta, I.; Olafsson, H.; Moniruzzaman, M.; Zhang, H.; Liou, Y.-A.; Mushore, T.D.; Gupta, A. Impacts of drought on vegetation assessed by vegetation indices and meteorological factors in Afghanistan. *Remote Sens.* **2020**, *12*, 2433. [\[CrossRef\]](#)

31. Ye, T.; Shen, Q.; Wang, K.; Zhang, Z.; Zhao, J. Interdecadal change of the northward jump time of the Western Pacific Subtropical High in association with the Pacific Decadal Oscillation. *J. Meteorol. Res.* **2015**, *29*, 59–71. [[CrossRef](#)]
32. Scott, D.; Rutty, M.; Amelung, B.; Tang, M. An inter-comparison of the holiday climate index (HCI) and the tourism climate index (TCI) in Europe. *Atmosphere* **2016**, *7*, 80. [[CrossRef](#)]
33. Lohmann, M.; Kaim, E. Weather and holiday preference—Image, attitude and experience. *Tour. Rev.* **1999**, *54*, 54–64. [[CrossRef](#)]
34. Perch-Nielsen, S.; Amelung, B.; Knutti, R. Future climate resources for tourism in Europe based on the daily tourism climatic index. *Clim. Chang.* **2010**, *103*, 363–381. [[CrossRef](#)]
35. Jiang, W.; Wang, Y.; Tsou, M.-H.; Fu, X. Using Social Media to Detect Outdoor Air Pollution and Monitor Air Quality Index (AQI): A Geo-Targeted Spatiotemporal Analysis Framework with Sina Weibo (Chinese Twitter). *PLoS ONE* **2015**, *10*, e0141185. [[CrossRef](#)]
36. Wang, Z.; Bai, T.; Xu, D.; Kang, J.; Shi, J.; Fang, H.; Nie, C.; Zhang, Z.; Yan, P.; Wang, D. Temporal and Spatial Changes in Vegetation Ecological Quality and Driving Mechanism in Kökyar Project Area from 2000 to 2021. *Sustainability* **2022**, *14*, 7668. [[CrossRef](#)]
37. Huang, J.; Guan, X.; Ji, F. Enhanced cold-season warming in semi-arid regions. *Atmos. Chem. Phys.* **2012**, *12*, 5391–5398. [[CrossRef](#)]
38. Held, I.M.; Soden, B.J. Robust Responses of the Hydrological Cycle to Global Warming. *J. Clim.* **2006**, *19*, 5686–5699. [[CrossRef](#)]
39. Schwedike, J.; Govekar, P.; Reeder, M.J.; Wardle, R.; Berry, G.J.; Jakob, C. Local partitioning of the overturning circulation in the tropics and the connection to the Hadley and Walker circulations. *J. Geophys. Res.* **2014**, *119*, 1322–1339. [[CrossRef](#)]
40. Schwedike, J.; Berry, G.J.; Reeder, M.J.; Jakob, C.; Govekar, P.; Wardle, R. Trends in the local Hadley and local Walker circulations. *J. Geophys. Res.* **2015**, *120*, 7599–7618. [[CrossRef](#)]
41. Huang, R.; Chen, S.; Chen, W.; Hu, P. Interannual variability of regional Hadley circulation intensity over western Pacific during boreal winter and its climatic impact over Asia-Australia region. *J. Geophys. Res.* **2018**, *123*, 344–366. [[CrossRef](#)]
42. Sun, Y.; Zhang, X.; Zwiers, F.W.; Song, L.; Wan, H.; Hu, T.; Yin, H.; Ren, G. Rapid increase in the risk of extreme summer heat in Eastern China. *Nat. Clim. Chang.* **2014**, *4*, 1082–1085. [[CrossRef](#)]
43. Cao, L.; Yan, Z.; Zhao, P.; Zhu, Y.; Yu, Y.; Tang, G.; Jones, P. Climatic warming in China during 1901–2015 based on an extended dataset of instrumental temperature records. *Environ. Res. Lett.* **2017**, *12*, 064005. [[CrossRef](#)]
44. Cheng, Q.; Yan, Z.; Wu, Z.; Fu, C.; Tu, K. Trends in temperature extremes in association with weather-intraseasonal fluctuations in eastern China. *Adv. Atmos. Sci.* **2011**, *28*, 297–309. [[CrossRef](#)]