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SPATIAL-TEMPORAL PATTERNS OF TRAVEL CLIMATE COMFORTABLE PERIOD IN NORTHEAST CHINA FROM 1981 TO 2010

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As a kind of time scale to the assessment of travel climate comfort degree, travel climate comfortable period (TCCP) is of significance to tourism development, such as architectural design of the tourism scenic spot, health of the tourists, and regional tourism development strategy under climate influence etc. Most of studies on TCCP generally took month-scale as the time granularity, which was too long to precisely chart the intra- or inter- regional differences. TCCP spatial and temporal characteristics of Northeast China from 1981 to 2010 in day-scale are described. Based on the daily meteorological data from 98 basic weather stations in Northeast China, including Heilongjiang province, Jilin province, and Liaoning province, this paper made use of Temperature Humidity Index and Wind Chill Index, and built the compound model based on them to assess the climate comfortableness of this area in the past 30 years since the 1980s. This study indicates the average annual and seasonal TCCP and its spatial patterns in Northeast China. The research results can provide the basic cognition and important reference of the travel health guarantee and climate environmental adaption for the tourism development in this area.

Keywords: *travel climate comfortable period, Northeast China, Temperature Humidity Index, Wind Chill Index, tourism development.*

Introduction

The travel climate comfortable degree is one of the biometeorological indices which aims to evacuate travelers' comfort condition under the different climate cases and it is stipulated by the heat exchanging theory between human organisms and the environment [1]. The discrepancy of the index causes the variation of travel climate comfortable period (TCCP) distribution and the seasonal characteristic in the recreation area directly. So it makes critical effect on the architectural design of the scene spot [2], the health of tourists [3] and the development of tourism industry. During the past half century, with the differential region climate response which caused by global warming, the travel climate comfortable degree and period of the different region has varied differently [4]. Acting as the ruler which is able to measure the travel climate comfortable duration, TCCP characterizes the travel climate comfortable degree intuitively and numerically. In the initial survey, a large amount of researchers define TCCP by using the month-scale as the time granularity. However, compared with the method by using the day-scale as the time granularity, the definition is too long to precisely chart the intra- or inter- regional differences of the study area.

The area between China and Russia is extensive and resourceful. Owing to the complexity of the land cover types and the huge span of its longitude and latitude, the climate change makes different impact on the different area in this region. So it is essential to develop the investigation on the spatial-temporal patterns of TCCP totality in this region. This survey choose the north-east region of China which is adjacent to Russia as the study area and try to describe spatial and temporal characteristics of TCCP in Northeast China from 1981 to 2010 based on day-scale method.

Data sources and research methods

The study area of this paper includes Heilongjiang province, Jilin province, and Liaoning province in China. The climate data resource of the area is from China Meteorological Science Data Sharing Service Website (http://cdc.cma.gov.cn/). The data comment includes three kinds of daily ground climate data: air temperature, wind speed and relative humidity which were collected by 98 meteorological datum stations within the study area from 1981 to 2010.

This paper draw lessons from the division method of season in meteorology field. The beginning/end date of TCCP is defined by the rule that the first day of one week in which the temperature and humidity index (THI) and the wind chill index (WCI) are within/out the range of "comfort" threshold. The model expression of THI is shown in (1); the model expression of WCI is shown in (2):

$$THI = t - 0.55(1 - 0.01RH)(t - 14.5) \quad (1)$$

$$WCI = (33 - t)\left(9 + 10.9\sqrt{v}\right) - v \quad (2)$$

where t is air temperature (°C), RH is relative humidity (%), v is wind speed (m s^{-1}).

In this paper, the classification standard of the above indexes is scientifically identified by the meteorological data of Northeast China, and the "comfortable" threshold scope of the study area is further defined. Firstly, the daily WCI values of 98 datum meteorological stations in Northeast China during 1981–2010 are calculated, and the corresponding temperature distribution information of these values in their nine grade division is counted.

According to the comfort period definition of this study, the beginning and end dates of the monthly travel climate comfort period of the Northeast China in recent ten years (2001–2010) are determined and the results of the 10 year comfort period are averaged, the beginning and expire time of the monthly average travel climate comfort period of the city level during 2001–2010 is finally obtained. This time period can be used as the reference time for tourists to carry out tourist activities in the corresponding month.

Spatial pattern characteristics

Based on the combined model strategy and the corresponding comfort threshold criteria, the climate comfort period of 1981–2010 in Northeast China was calculated by the equations (1) and (2). Based on ArcGIS software and spatial interpolation carried out by using the common Kriging interpolation method according to the calculation results, the spatial distribution of annual average TCCP (Figure 1) and quarterly average TCCP (Figure 2) in Northeast China are obtained.

As shown in Figure 1, the annual average

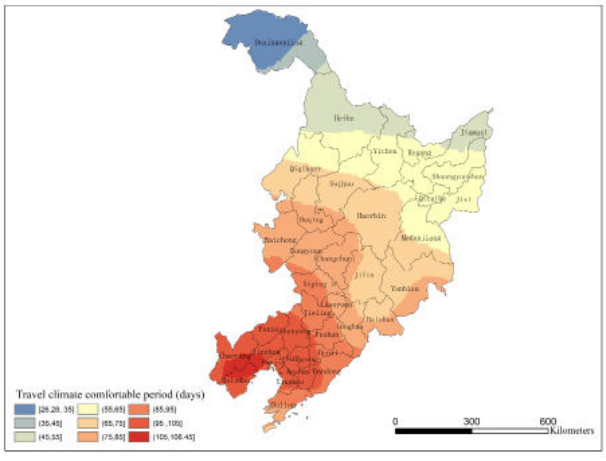

Figure 1. Spatial distribution of the annual average climate comfortable period in Northeast China from 1981 to 2010

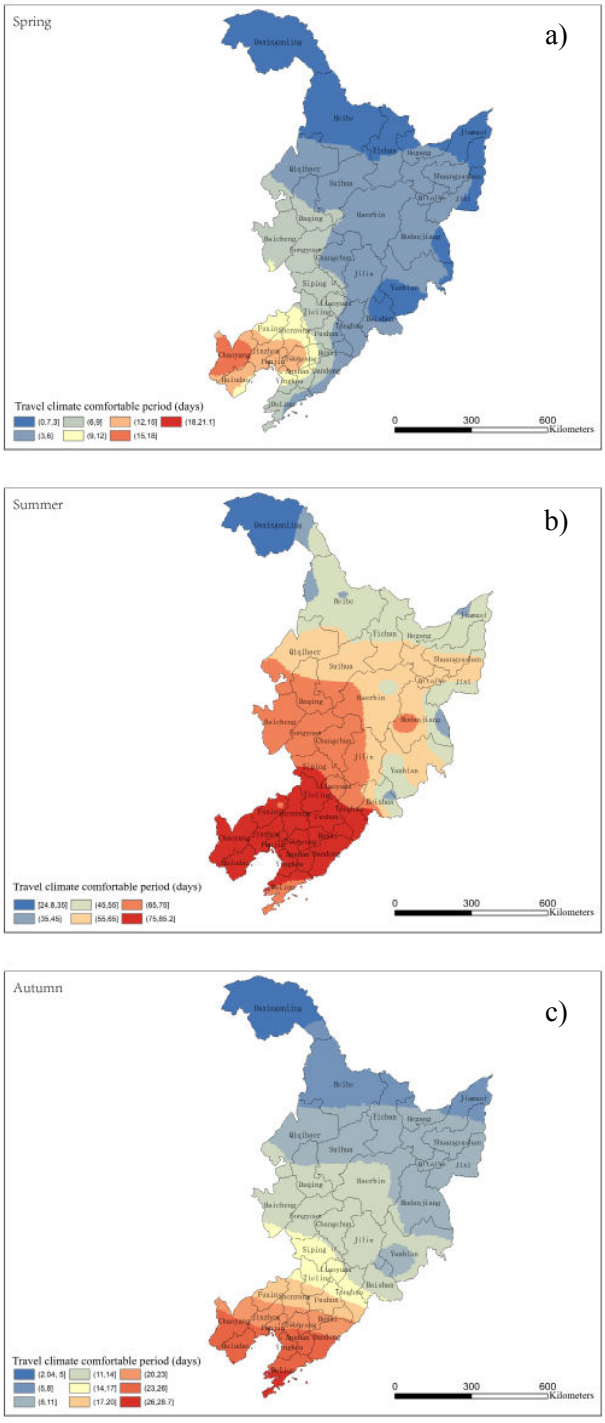

Figure 2. Spatial distribution of the seasonal average climate comfortable period in Northeast China from 1981 to 2010 (a represents Spring, b represents Summer, c represents Autumn)

TCCP in Northeast China has a spatial pattern of "long in southeast and short in northwest", with the longest TCCP in the adjacent area among the cities of Jinzhou, Huludao and Chaoyang in Liaoning province. The TCCP lasts 106.45 days. The shortest TCCP occurs in Greater Khingan Range, Heilongjiang Province, and the duration is 26.28 days. It can be clearly seen that the annual TCCP in Northeast China has gradually increased with the decrease of the latitude.

As shown in Figure 2(a),during the spring season, the TCCP of Northeast China generally maintained a similar spatial pattern with the annual average TCCP. The TCCP in Northeast China is generally low in spring and the longest comfort period is 28.7 days. It appears in the area under the jurisdiction of Chaoyang in Liaoning province. The shortest comfort period is only 0.7 days, and it still appears in Greater Khingan Range, Heilongjiang province. It indicates that the climate comfort condition in Northeast China is not optimistic in spring.

As shown in Figure 2(b), for the visitors to the study area, the summer of Northeast China is the most ideal season for the four seasons in this region, of which most of the cities in Liaoning and some cities in southern Jilin are within the range of 75~85.2 days, which are very suitable for tourists to travel. With the highest latitude in the region, Greater Khingan Range have the shortest TCCP, the interval lasts 24.8 days. However, compared with other seasons, the summer TCCP in this area has increased significantly.

As shown in Figure 2(c), during the autumn season, the TCCP in Northeast China is almost as the same condition as that in spring. The longest TCCP occurs in the area under the jurisdiction of Dalian, Liaoning province. The duration of the comfortable period is 28.7 days. The shortest TCCP still occurs in Greater Khingan Range, Heilongjiang province. The duration of comfortable period is 2.04 days.

According to the THI and WCI combined model strategy used in this paper, it is calculated that the whole region in Northeast China have no comfortable period in winter.

Law of historical evolution

Based on the annual and seasonal TCCP which are calculated by 98 datum meteorological stations in Northeast China from 1981 to 2010, the differences of TCCP mean values between 1996–2010 (latter 15 years) and 1981–1995 (former 15 years) is calculated in the whole region (hereinafter referred to as the two phase difference). On the one hand, the annual and seasonal differences in two phases have been counted. On the other hand, the spatial interpolation of the two phase difference is carried out by using the ArcGIS software.

The research shows that:

(1) The average annual TCCP in Northeast China from 1996 to 2010, compared with the former phase, shows the time evolution law of "little change in the north and South, more change in the middle". The most TCCP increased area locates in the cities of Jiamusi, Shuangyashan and Jixi in Heilongjiang Province, and the later period of comfort increased by 11.26 days compared with the previous phase. The most reduced areas of TCCP were found in parts of Western Liaoning and Western Greater Khingan Range, Heilongjiang province, and the later phase of comfort decreased by 2.4 days compared with the previous phase.

(2) During 1996–2010, the TCCP of Northeast China in spring is generally lower than that in the previous phase, of which the areas with the most descending of the TCCP occur in the 7 cities in the central Liaoning Province, and the latter phase is reduced by 4.47 days compared with the previous phase. In the northern part of Heilongjiang, the eastern part of Jilin province and the western part of Liaoning, TCCP in the later phase has slightly improved, the largest increase of which is 1.47 days.

(3) In summer, the time evolution of TCCP in Northeast China is similar to that of the annual TCCP. The TCCP of the border area among the cities of Jiamusi, Shuangyashan and Jixi in Heilongjiang has the largest increase (12.84 days) in 1996-2010 compared with the years in 1981–1995. There was a slight decrease of TCCP in some parts of Dalian and Huludao, Liaoning Province, with a maximum decrease of 0.9 days.

(4) During the 1996–2010, the TCCP in the southern cities of the Northeast China is higher than that of the previous phase. The largest increase area appears in the three seashore cities: Yingkou, Dalian and Panjin in Liaoning province with the increased 11.28 days. In the northern part of Greater Khingan Range, Heilongjiang, there was a slight decrease in the TCCP compared with the years of 1981–1995, with a maximum decrease of 2.39 days.

Conclusions

Based on the daily meteorological data of 98 datum meteorological stations in Northeast China for 1981–2010 years, this paper makes use of improved wind cold index (WCI) and temperature humidity index (THI) combination model strategy to analyze the spatial pattern and time evolution of TCCP in the northeast of China for last 30 years. The result shows that:

(1) According to the combined model of THI and WCL and the actual climate conditions in Northeast China, the annual and seasonal TCCP of the re-

gion is about 66.4 days, of which the longest (41.68 days) in summer, the spring and autumn (9.35 days and 15.37 days), and the shortest (0 days) in winter. The proportion of summer comfort period is about two times than that of the two seasons of spring and autumn.

(2) The seasonal climatic comfort period of the annual average and the two quarter of the spring and autumn period are presented as the spatial pattern of "long in southeast and short in northwest". The high value area of the summer climate comfortable period is mainly distributed in the southern coastal cities of the region. The temperate monsoon climate and the corresponding seasonal factors become the main influence of the longer comfort period in these cities. In winter, the research area has no TCCP. So the tourists, especially the old and the people in poor physical conditions, are advised to reduce travel time in the area. If necessary, essential precautions and cold-proof measures are needed.

(3) From the general point of view, the annual average TCCP in Northeast China has increased for nearly 30 years (1981–2010), and it has increased about 6.37 days in the last 15 years, of which the two quarter of summer and autumn have contributed about 90%. Compared with the previous phase, TCCP of the study area in spring is lower than that in the previous phase, but the decrease is relatively small, and the change of TCCP in this area is relatively stable.

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REFERENCES:

1. ANSI/ASHRAE Standard55-2010 (2010) Thermal Environmental Conditions for Human Occupancy [S]. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
2. Büntgen U, Tegel W, Nicolussi K, et al. (2011) 2500 years of European climate variability and human susceptibility. Science 331(6017): 578–582.
3. Shindell D, Kuylenstierna JCI, Vignati E, et al. (2012) Simultaneously mitigating near-term climate change and improving human health and food security. Science 335(6065): 183–189.
4. Qin Dahe (2014) Climate change science and sustainable development. Progress in Geography 33(7): 874–883.