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〈Research Article〉

An examination of the Tourism Holiday Index (HCI:Urban) in Tokyo 1964-2019

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Abstract

Climatic conditions have a significant influence on visitors' destination decision-making and their perception of a destination. Tourism is thus highly dependent on the climatic conditions of the places tourists visit. With climate change an accepted scientific fact, it is likely that future climate will impact the health and well-being of tourists and negatively affect the tourism industry itself. For cities like Tokyo with a sub-tropical summertime climate and considerable investment in tourism infrastructure, climate change may render summertime tourism to Tokyo dangerous or even unviable. For these reasons a better understanding of Tokyo's tourism climate resource is vital. Using the Holiday Climate Index (HCI:Urban), this research examines the long-term tourism climate record in Tokyo between 1964 and 2019. Findings suggest greater climatic variability, and a decline in the favorability of Tokyo's tourism climatic resources in all three summer months. According to these findings, adaptation and mitigation strategies are recommended and a Japanocentric tourism climate index proposed.

Keywords: holiday climate index, climate change, urban tourism, tourism climate resource

1. Climate change, tourism climate and Tokyo

For more than a decade prior to the emergence of the global Covid-19 pandemic in January 2020 it was climate change not the coronavirus that was the preeminent issue of global sociopolitical discourse (Katz, 2008). Following the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, changes in global climate have become the focus of increasing academic attention and have become better cognized by the public at large (Ciscar, 2014). In the academic community there has been interest in a diverse range of climate change issues including the 2003 European heatwave of 2003 (Robine, Cheung, Le Roy et al., 2008), the intensification of Caribbean hurricanes (Amelung, Nicholls, and Viner, 2007), the decrease in winter snow cover in ski resorts (Damm, Gruell, Landgren et al., 2017), the increased risk posed by wildfires (Dowdy, Ye, Pettler et al., 2019), and the loss of coastal environments - including beaches - to rising sea levels (Jones and Phillips, 2018). At the same time, in the last two years public consciousness of climate change has grown as activists such as Greta Thunberg champion a “climate crisis” (Watts, 2019), a notion embraced by public figures including the UN Secretary General who gave mention to “global heating” in place of “global warming” in his address to the UN in late 2019 (United Nations, 2019). Saliently, the “crisis” has been recognized as a threat to the viability of the tourism industry in key destinations around the world for more than a decade (Rutty and Scott, 2010).

As the natural resource upon which tourism is “predicated” (Scott, and McBoyle, 2001), climate plays a major role in all stages of the tourist experience from destination choice through to visitation of the destination itself (Matzarakis, 2008; Scott, Hall and Gossling, 2012). Given the World Meteorological Organization’s 2019 announcement that the last decade was one of “high impact” weather (WMO, 2019), and the IPCC’s AR5 “highly confident” stance that climate change will be “primarily negative” in city environments (Solomon, Qin, Manning et al., 2007, p.180), it seems likely that changes in climate due to “global heating” will have a strong bearing on future tourist activity (Kubokawa, Inoue and Sato, 2014), and tourist comfort (Kasai, Okaze, Yamamoto et al., 2017) in places like Tokyo. This is likely to affect the future temporal and spatial distribution of tourism, and consequently realign the season, duration and locations in which tourism can be successfully maintained (Grillakis, Koutroulis, Seiradakis et al., 2016; Amelung et al., 2007). Due to Japan’s rapid growth as an international visitor destination - highlighted by the planned hosting of the 2020 Summer Olympiad - Tokyo is one city where the confluence of tourism, climate, and climate change has taken on increased significance.

Tokyo attracted more than 15 million overseas visitors in 2019 (Tokyo Metropolitan Government, 2020) and has now become one of the world’s most visited international urban destinations. Although Tokyo’s temperate climate with four distinct seasons is an important pull factor for South East Asian visitors in winter (Xu and Tavitiyaman, 2016), its summer months are marked by a combination of uncomfortably high temperatures and humidity, as much as 80% of annual precipitation, and as many as 5 - 6 typhoons (Matzarakis, 2008). The difficulties associated with Tokyo’s summer conditions are well-known to Tokyoites and the city has well-established systems to disseminate heat comfort information to residents (Sanchez-Martinez, Imai, and Masumo, 2011) and tourists alike (MLIT, 2017). Despite these measures during preparations for the Tokyo 2020 Olympics biometeorological studies, which highlighted the risks of heatstroke to visiting athletes and spectators (Coudevylle, Sinnapah, Robin et al., 2019; Honjo, Yuhwan, Yamasaki et al., 2018), led to the unprecedented decision to relocate events including the marathon to Sapporo 800km north of Tokyo. Emphasizing the extreme summer conditions in the city, locally sourced primary data indicates heat exhaustion in July, August and September can be fatal (Fire and Disaster Management Agency, 2018), and even mundane tourist activities such as walking outdoors have been found to be too uncomfortable for the vast majority of Tokyo’s summertime visitors (MLIT, 2019).

2. Tourism biometeorological research in Japan

Despite a plethora of interest in the relationship between tourism, climate and climate change in Europe and North America (Rutty, Scott, Mathews, Burrowes et al., 2020; Scott, Hall, and Gossling, 2019), there is a relative paucity of research in biometeorology for tourism in Japan (Ichinose, Matuschek, and Jing, 2008) to inform the current research. The earliest of any such studies can be traced to Aoki and Aoki (1974), and Aoki and Fujinuma (1997) who examined the role of weather on day leisure visits, together with later work by Fujinuma and Aoki (1998), and Fukushima, Kurha, Ozaki et al. (2003) which both linked meteorological variables to ski tourism demand. More recent studies have uncovered how climate change has affected visitation in the domestically important niche of flower and plant tourism (Inoue and Nagai, 2015; Liu, Cheng, Jiang et al., 2019). Meanwhile, a study conducted in Okinawa (Watanabe, Iida, Nakatani et al., 2016) established a link between the incidence of precipitation and tourist satisfaction in the archipelago.

Of greater relevance to the current research is the work of Matzarakis (2008), who drew up physiological equivalent temperature (PET) maps of Japan to indicate contemporary tourist comfort, and Kubokawa et al. (2014) who employed the Tourism Climate Index (TCI) to examine historical meteorological data and chart the influence of climate change on tourism in the future. The latter study indicating that spring and autumn are likely to be more favorable for tourism than summer. Though both these studies inform the current research they were mesoscale in nature which obscures processes at an individual city scale. Moreover, some summary findings, such as “summer is the most comfortable season for tourism [in Japan]” (Kubokawa et al., 2014, p.14), are generalizations that contradict the latest Japan-based heat disorder risk research which shows outdoor heat stress in Tokyo has increased and is likely to worsen under all probable global warming scenarios (Kasai et al., 2017; Ohashi, Ihara, Kikegawa et al., 2016). Importantly, there have been no studies which evaluate the suitability of tourist visits to Tokyo in the summer months using a climate composite index appropriate for urban tourism. Given Tokyo’s status as a leading international urban destination this is a notable omission. The current research is an attempt to fill some of the paucity in this record.

3. The development of tourism climate indices and the Holiday Climate Index (HCI)

Evolving from indices built for use in health and agriculture, tourism climate indices are tools which use raw meteorological data to holistically describe the suitability of a given climate to tourism activities. Such indices have been applied widely to compare climate resources and their impacts on tourism for more than 35 years (Rutty, Scott, Matthews et al., 2020). By combining the complex interaction of different climatic variables (generally air temperature, humidity, rainfall, sunshine/cloud cover and wind), tourism climate indices are seen as the simplest way to quantify the climate relevant to tourism. Each index is a composite (in the form of an equation) for which variables and weightings are unchanged regardless of season or location, and thus direct comparison between spatially different locations and temporally different times at one given location can be made.

The first composite index designed for evaluating tourism resources was the Tourism Climate Index (TCI) developed by Mieczkowski (1985), and despite the emergence of other subsequent indices it continues to be the most commonly applied index to tourism/climate studies (Scott, Rutty, Amelung et al., 2016). The TCI is composed of 5 sub-parts; *daytime comfort* measured by maximum temperature and minimum humidity; *daily comfort* which combines mean daily temperature and mean humidity; *precipitation*; *hours of sunshine* and; *wind speed*. Each of these five sub-parts is assigned a rating to a maximum of 5, and presented in the composite equation described in (1):

$$TCI = 2 \times (4(\text{daytime comfort}) + \text{daily comfort} + 2(\text{precipitation}) + 2(\text{sunshine}) + \text{wind}) \quad (1)$$

Despite its popularity the TCI has a number of weaknesses that make it “inappropriate” for use in assessing the climate in all tourism settings (Scott et al., 2016). According to de Freitas, Scott and McBoyle, (2008), and Scott and McBoyle, (2001), the principal weakness is in the weightings assigned to each sub-part of the index which were fixed according to Mieczkowski’s subjective opinion on what a ‘suitable’ tourism climate is. A second issue is the TCI’s use of “daily comfort” which assumes nighttime conditions play a significant part in visitors’ experiences. When the TCI was devised (1985) this may have been a reasonable assumption since air conditioning was not universal at destinations, however today the majority of tourist accommodations have air conditioning installed as standard making nighttime weather conditions a less important consideration. More controversially, research subsequent to 1985 has questioned the 50% weighting ascribed to thermal comfort in the TCI. For example, Nikolopoulou & Steemers (2003) have shown that leisure visitors in outdoor spaces will accept thermal conditions that exceed physiological comfort and argue a 50% weighting for thermal comfort may not be warranted. The TCI also fails to account for aesthetic factors such as cloudiness, which visitors consider important for activities such as photography (de Freitas et al., 2008), and is poor at internalizing heavy rainfall, and strong wind which can affect the visitor experience in places with sub-tropical conditions (Rutty et al., 2020). Finally, as an index representing *general* sightseeing the TCI fails to take account of tourists’ different climatic needs in different tourist settings (e.g. between beach and urban tourists).

In response to these inherent weaknesses in the TCI Scott et al. (2016) proposed the Holiday Climate Index (HCI) with separate sub-indices for urban and beach tourism. The strength of the HCI over the TCI can be found in the fact that its components and their respective weightings are based on the findings of empirical studies in different tourist settings rather than being a result of subjective opinion. The HCI also better internalizes aesthetic and physical elements as recommended by de Freitas et al. (2008) by weighting cloud cover, rainfall and wind speed more effectively. The HCI is thus comprised of: *thermal comfort* (TC) which combines maximum temperature (ºC) and mean relative humidity (%); *an aesthetic factor* (A) (cloud cover %); and a *physical* component (P) made up of precipitation (mm) and wind speed (m/s). In its urban manifestation (HCI:Urban), it is calculated using equation (2):

$$\text{HCI: Urban} = 4\,(\text{TC}) + 2(\text{A}) + 3\,(\text{precipitation}) + \text{wind} \qquad (2)$$

As shown in (2) and Table 1, thermal comfort makes up 40% of the HCI:Urban (i.e. 10% less than the TCI), with the aesthetic factor (cloudiness), and physical components (rain and wind) contributing a further 20% and 40% respectively. The individual ratings for each index component are shown in Table 2. As indicated each climatic component is rated on a scale of 0 to 10 and the composite HCI:Urban calculated using equation (2). The resulting HCI value is in the range 0-100 with HCI 0 considered as "potentially dangerous to tourism" and 100 rated as "ideal for tourism" (Table 3). As a more robust measure for assessing tourism in an urban environment to the TCI, the Holiday Climate Index:Urban (HCI:Urban) was selected as the main tool of analysis to evaluate the suitability of Tokyo's climate to summertime tourism in the current research.

Table 1. Comparison of climate index weights HCI:Urban and TCI

Index Component	Weather Variable	TCI	HCI:Urban
Thermal comfort (TC)	Temp & relative humidity	50%	40%
Aesthetic (A)	Cloud cover (%)	20%	20%
Precipitation (P)	Total precipitation (mm)	20%	30%
Wind (W)	Mean wind speed (m/s)	10%	10%
Overall index score range		-30 to 100	0 to 100

Table 2. Holiday Climate Index Components Rating System

Rating	**Humidex Value (C)**	**Mean Daily Precipitation (mm)**	**Mean Cloud Cover (%)**	**Mean Wind Speed (km/hr)**
10	23.0-25.9	0	11-20.9	0.1-9.9
9	26.0-26.9	0.01-2.99	1.0-10.9	10.0-19.9
8	27.0-28.9	3.00-5.99	0-0.9 and 31-40.9	0.0 and 20.0-29.9
7	29.0-30.9	-	41-50.9	-
6	31.0-32.9	-	51-60.9	30.0-39.9
5	33.0-34.9	6.00-8.99	61-70.9	-
4	35.0-36.9	-	71-80.9	-
3	-	-	81-90.9	40.0-49.9
2	37.0-38.9	9.00-11.99	91-99.9	-
1	-	-	100	-
0	≥39.0	12.00-24.99	-	50.0-69.9
-1	X	≥25	-	≥70

Source: Scott, Rutty, Amelung and Tang (2016)

To complement the modifications made by Scott et al. (2016) in developing the HCI, in the current research a further refinement to the index was piloted. Tourism climate indices generally cover climatic conditions over a 24-hour period, however it would seem this does not effectively represent the hours most tourists are experiencing, or being affected by meteorological conditions. In the same way the HCI does not measure daily thermal comfort due to the ubiquity of air conditioning, it would therefore seem appropriate to have an index in which the physical components of the HCI (rainfall and wind speed) better reflect hours when urban tourists are active outdoors. As a result, in the current research, two HCI Urban indices were considered: one to represent the full 24-hour period (HCI:Urban$_{24}$) and one for which rainfall and wind data are omitted between the hours of 10pm and 6am (i.e. hours tourists are generally not active outdoors). This index is referred to as the HCI:Urban$_{16}$ in the current study.

Table 3. Holiday Climate Index (HCI: Urban) rating system

Score	Descriptive Rating
90 - 100	Ideal
80 - 89	Excellent
70 - 79	Very good
60 - 69	Good
50 - 59	Acceptable
40 - 49	Marginal
30 - 39	
20 - 29	Unacceptable
10 - 19	
0 - 9	Dangerous

4. Aims and Method

Using the HCI:Urban as the tool of analysis, the aim of the current research is to explore Tokyo's July, August and September (JAS) longitudinal meteorological record in order to better understand the suitability of the city to summertime tourism. The base year was chosen as 1964, partly to give the research a long-term perspective, but also to frame the research in terms of the years Tokyo hosted the Olympic Games (1964) and was due to host the Games (2020). Japan's Basic Tourism Law also came into being in 1964 thus the year is an important benchmark for international tourism in Japan. Summertime was defined in terms of JAS rather than the Japan Meteorological Agency (JMO) standard of June, July August (JJA) since preliminary data analysis indicated that in the 5 most recent years (2015-2019) the Canadian Humidex value in Tokyo in September (=39C) more closely resembles 'summer' to that of June (=35C) (Canadian Humidex is a tool commonly utilized in biometeorology for tourism studies (Rutty et al., 2020; Scott, et al., 2016)). At the same time, by including September it was hoped that new insights into the tourism climate resource of one of Tokyo's lesser visited months might be possible (JNTO, 2020).

Meteorological data for the current study was drawn from the publicly available online records of the Japan Meteorological Agency (JMO, 2020) for the Otemachi weather station, Tokyo (35° 41.5", 139° 45"). The rationale for choosing Otemachi from the 11 official weather stations in Greater Tokyo was based on: (1) Otemachi has the longest, continuous record of meteorological records; (2) Otemachi records the largest number of meteorological variables, and; (3) Otemachi is the geographically closest weather station to Tokyo's major tourist sights.

To establish a longitudinal HCI:Urban profile for Tokyo JAS, hourly data for air temperature, relative air humidity, precipitation, windspeed, and cloud cover at the Tokyo Otemachi weather station for the period 1964 to 2019 was downloaded from the JMO webpage with the 24-hour record used for the HCI:Urban$_{24}$ and a 16-hour period (06:00~22:00) for the HCI:Urban$_{16}$. Analysis was made operational via the Canadian Humidex to calculate the thermal comfort (TC) values and equation (2) in section 3. The data was processed through a "desk-top" research approach using the excel application. The key research questions were:

1) How has the suitability of Tokyo's JAS climate to tourism changed longitudinally?
2) How suitable are Tokyo's climate resources for JAS visitation today?
3) In light of the findings, what recommendations can be made for JAS tourism in Tokyo and the HCI:Urban as an index for measuring climate resources.

5. Results

5.1 The meteorological record

Before examining the HCI:Urban for Tokyo JAS it is instructive to explore the decadal and annual trends over the 56-year period for each meteorological variable (air temperature, relative humidity, precipitation, cloud cover and wind speed) that makes up the index.

5.1.1 Air Temperature

Air temperature is perhaps the most commonly used - and best understood – meteorological variable to describe weather and climate and forms part of the HCI:Urban thermal comfort calculation. Table 4 shows Tokyo's JAS mean air temperature for three 30-year periods (1961-1990, 1975-2004 and 1990-2019) and indicates a steady rise in temperature of 0.9°C from 24.6°C for 1961-1990 to 25.5°C for 1990-2019. This increase is apparent in all three summer months with July showing the greatest change (+1.2°C, 25.2~26.4°C), and September (+0.9°C, 23.2~24.1°C), and August (+0.5°, 27.1~27.6°C) showing lesser, but still significant, increases. These increments are similar in size to the increases seen across the other 9 months of the year (+1°C) (Table 4).

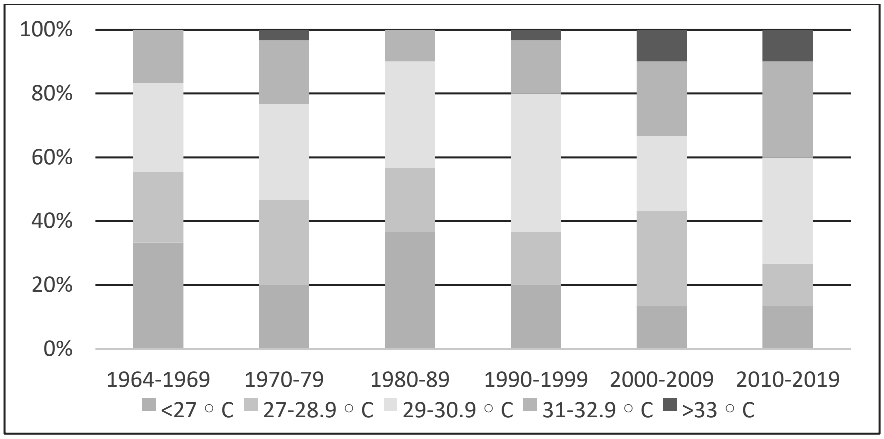
Table 4. 30-year mean Tokyo JAS air temperature (°C)

30-year period	Mean air-temperature (°C)				
	July	Aug	Sept	July-Sept (inclusive)	Jan-Dec Excl. JAS
1961 - 1990*	25.2°	27.1°	23.2°	24.6°	12.4°
1975 - 2004	25.7°	27.1°	23.7°	24.9°	13.0°
1990 - 2019	26.4°	27.6°	24.1°	25.5°	13.4°

*note: 1961-1990 is the standard period for mean WMO data.

In place of mean air-temperature the HCI adopts daily *maximum* air temperature to calculate thermal comfort. Figure 1 describes the mean monthly maximum temperature (Tmax) by decade in 5 temperature ranges (Tmax <27°C, 27-28.9°, 29-30.9°, 31-32.9°, and Tmax >33°) and reveals two trends. Firstly, the share of Tmax <29°C has declined from about 50% of JAS in the 1960s, 1970s and 1980s to less than 30% in the 2010s. Secondly it shows a concomitant increase in the ratio of Tmax >31°C from less than 20% of JAS in the 1960s ~ 1990s to 40% in the 2010s.

Figure 1. Japan JAS average Tmax (ratio of days by decade)



As figure 1indicates, the main changes can be found at the extremes of the temperature record and this is particularly true for the *increase* in JAS days with absolute temperature maxima greater than 35°C (Tmax >35°C). Detailing this, Table 5 shows that Tmax >35°C days accounted for 1~1.6% of Tokyo JAS days in the 1960s, 1970s and 1980s (i.e. around one day per year) but have increased sharply in the last 30 years to 8.6% (i.e. about 8 days/year) in the 2010s. In 2019 alone there were 12 such days including a September day of 36.2°C.

Table 5. Tokyo JAS days with Tmax >35ºC

	Days per month (by decade)					
	1964-69*	1970-79	1980-89	1990-99	2000-09	2010-19
July	1	1	0	14	14	24
August	6	13	6	21	20	49
September	0	1	3	3	1	6
Decade Total	7*	15	9	38	35	79
% of JAS days	1.5%	1.6%	1%	4.1%	3.8%	8.6%

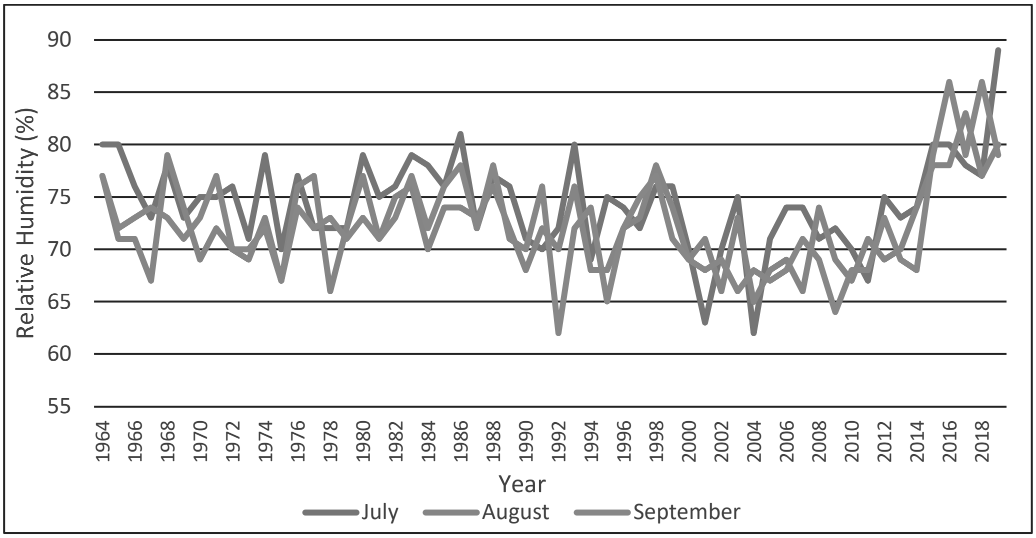
Note: 1960s data is a 6-year period (1964-69)

Thus on a decadal basis we can see there have been clear and measurable changes in mean air temperature, daily maximum temperature and a significant increase in the frequency of days with exceptionally high temperatures in Tokyo JAS over the 56-year period between 1964 and 2019. Such changes are likely to have a major impact on the way tourists experience Tokyo in summer.

5.1.2. Relative Humidity

To calculate thermal comfort, which accounts for 40% of the weighting in the index, the HCI:Urban combines mean daily maximum air temperature with mean relative humidity using Humidex or similar thermal perception calculation tool. Figure 2 traces the mean relative humidity (%) record for each summer month in Tokyo JAS for the 56-year period under study.

Figure 2. Tokyo JAS Mean Relative Humidity (%) by month 1964-2019



Tokyo mean monthly JAS relative humidity (RH) fluctuates considerably from year to year making a detailed analysis complex, nevertheless three distinct periods can be identified: (1) 1964 - the mid-1990s when RH moved within a limited amplitude of 65%~80%; (2) the mid-1990s - 2014 when RH decreased slightly, fluctuating mostly between 60% and 75%, and; (3) 2015 to the current day during which time fluctuations in RH have risen sharply to 75~85% (reaching a peak of 89% in July 2019). These observations should concern those associated with the well-being of tourists and tourism since even modest increments in humidity in sub-tropical climates can substantially increase the frequency of uncomfortable and "deadly" conditions (Matthews, 2018).

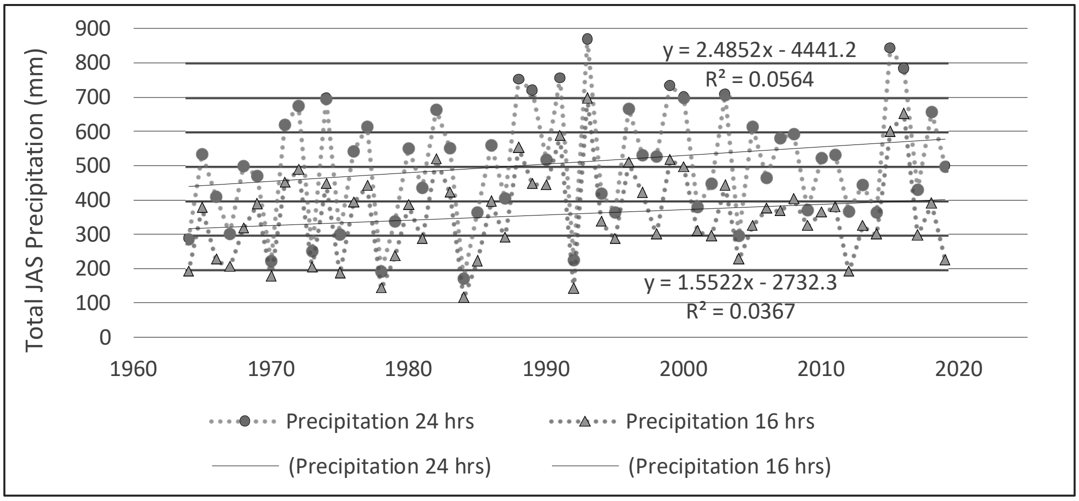
5.1.3 Precipitation

Precipitation is given a 30% weighting in the HCI:Urban and as such has a strong bearing on the outcome of the index. Since the role of precipitation is the rationale for piloting the HCI:Urban$_{16}$ in the current research, changes in this metric over the 1964-2019 period deserve detailed consideration.

In keeping with the sub-tropical nature of its summer climate, Tokyo's mean precipitation for the full day 24-hour period of the 3 JAS months (Ppt24) was slightly in excess of 500mm (mean=508mm) for the 56-year record with the equivalent 16-hour (06:00~22:00) value (Ppt16) 359mm, giving a daytime rainfall ratio (Ppt16/Ppt24) of 71%. As figure 3 shows there is considerable year to year variability around these mean values. For example, while in 1978 and 1984 Ppt24 was just 175mm and 195mm respectively, in 1993 and 2015 it was 869mm and 843mm. Similar variability can be found in the Ppt16 record.

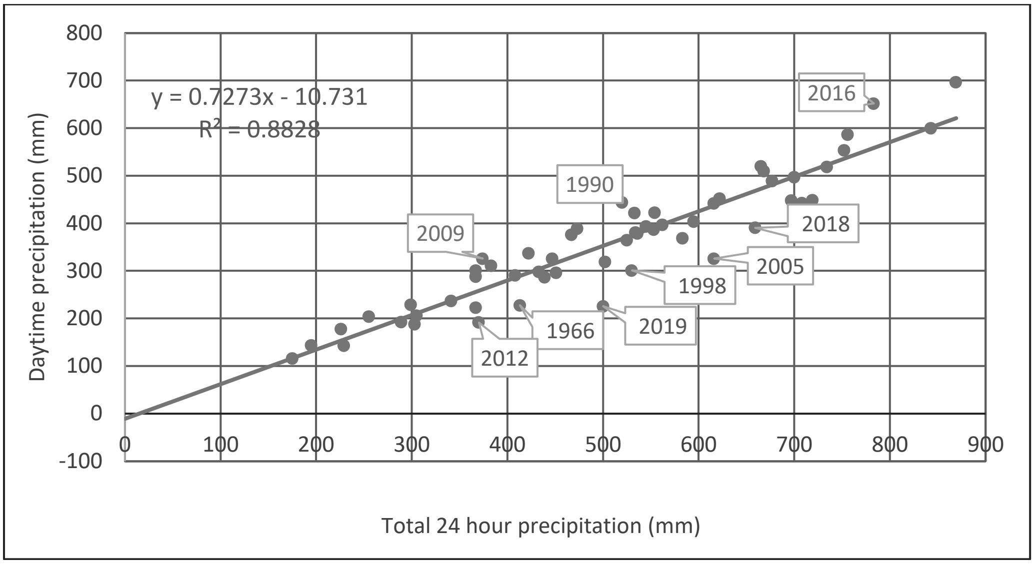
In addition to annual variability, according to linear regression there is a gradual longitudinal increase in JAS rainfall for both the 24-hour and 16-hour periods (figure 3). Moreover, as indicated by the slight divergence between the two regression lines, the rate of increase in Ppt16 and Ppt24 is different with 24-hour precipitation increasing at a rate of 2.49mm per year, and the 16-hour period advancing 1.55mm. This indicates an annual increase of 0.94mm/year in the ratio of nighttime rainfall. There is some evidence to suggest the rate of increase in nighttime rainfall has accelerated in the last 30 years.

Figure 3. JAS Precipitation (mm) 1964 – 2019



The tendency towards more variability and increased nighttime rainfall in recent years is verified by the regression analysis of Ppt16 and Ppt24 (figure 4). As we might expect there is close correlation between the 16-hour and 24-hour precipitation records (R^2 =0.8828) but there has also been a marked increase in annual variability since the 1990s with anomalously high *daytime* (2009, 2016) *and nighttime* rainfall (2005, 2012, 2018, 2019) in six of the most recent 15 years. 2009 (87%) and 2019 (45%) represent the two extremes in the 56-year record.

Figure 4. Tokyo JAS daytime (06:00~22:00) vs 24-hour precipitation



Note: highlighted years are statistically significant outliers (see Table 6).

Chi^2 analysis provides confirmation that variability in the Ppt16:Ppt24 ratio is statistically significant (Table 6). The years with the strongest significance *($p<0.05$, $df=1$)* being 2005, 2012, and 2019 when nighttime precipitation was greater, and 1990, 2009, and 2016 when daytime rainfall was at a premium. Such patterns of statistically significant variability in rainfall are expected under all global warming scenarios (IPCC, 2018), and supports the need to modify the HCI:Urban into 16-hour and 24-hour hybrids.

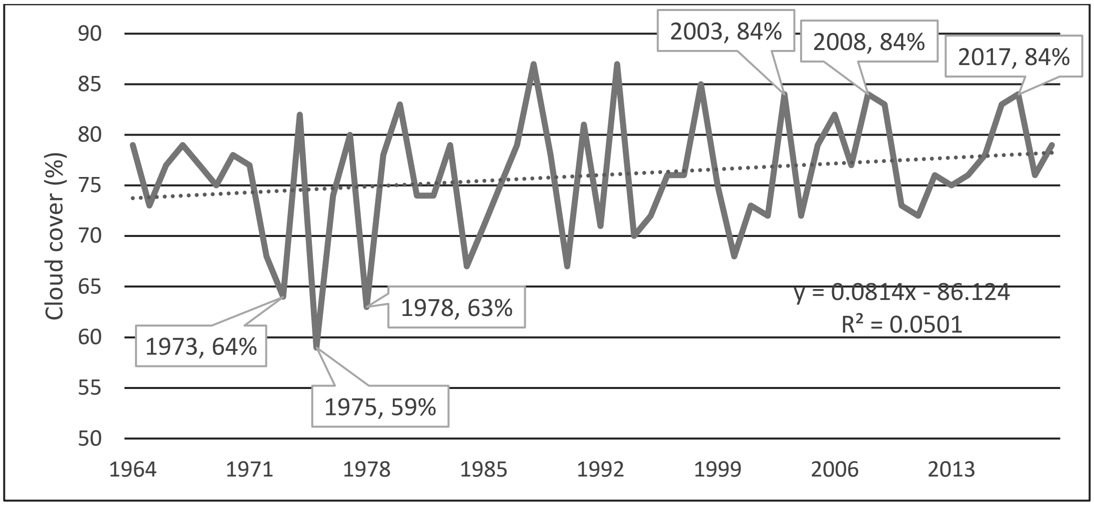
Table 6. Chi^2 values for anomalous rainfall years in Tokyo JAS

Year	Chi^2	Significance (p) df=1	Direction of anomaly (daytime/nighttime)
1966	5.28	0.02	Nighttime
1990	4.01	0.04	Daytime
1998	4.8	0.03	Nighttime
2005	8.87	0.003	Nighttime
2009	4.19	0.04	Daytime
2012	7.55	0.006	Nighttime
2016	3.56	0.05	Daytime
2018	3.47	0.06	Nighttime
2019	17.96	0.000023	Nighttime

5.1.4 Cloud cover

As the HCI:Urban's aesthetic factor, cloud cover contributes 20% of the variance to the index. As we might expect of a sub-tropical climate, Tokyo JAS cloud cover is relatively high averaging 76% but fluctuating between 60% and 85% (figure 5). A weak regression coefficient ($R^2 = 0.0501$) hints at a 4~5% increase in cloudiness over the 56-year period. Supporting this assertion, statistically significant JAS cloud cover minima in 1973 (64% cloud cover), 1975 (59%), and 1978 (63%) are contrasted by higher than average - but not statistically significant - cloud cover maxima in the two most recent decades (e.g. 2003, 2008, and 2017 all recorded 84%). These figures point to a decline in the overall climatic favorability of Tokyo to summertime tourism caused by cloud cover.

Figure 5. Tokyo JAS Cloud Cover (%)



5.1.5. Wind speed

Wind speed accounts for just 10% of the variance in the HCI:Urban, but can be a highly influential meteorological variable on tourist experience in Tokyo where high wind velocity weather events such as typhoons can occur at relatively short notice and disrupt transport-reliant plans before, during, and after occurrence.

Figure 6. Tokyo JAS mean wind speed (m/s)

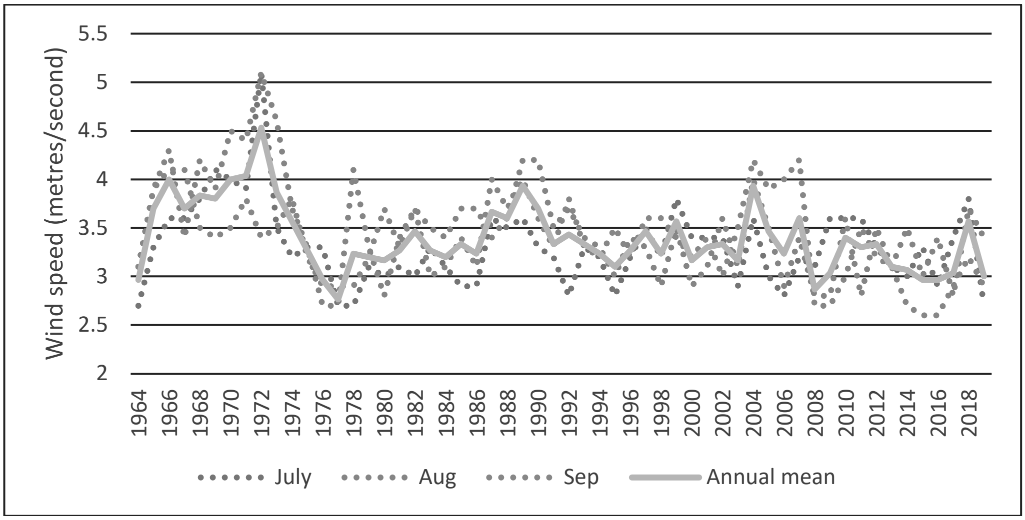


Figure 6 shows Tokyo JAS mean annual wind speed and indicates that it fluctuated within a narrow range of 3~4m/s for most of the 56-year record, with just 3 years 1972 (4.5m/s), 1977 (2.8m/s), and 2008 (2.9m/s) outside this range. In recent years a trend towards slightly lower mean wind speeds

(~0.2m/s lower) is apparent, but is not statistically significant. Since wind speed weighting is 1/10 of the index total, such changes are likely to have a limited impact on the HCI:Urban and the favorability of Tokyo's climate to summertime visits.

Based on the descriptive analysis of the meteorological variables which make up the HCI the following conclusions can be drawn about changes in Tokyo's JAS climate between 1964 and 2019:

1) There is a long-term trend of increasing JAS air temperature (~+1°C) in Tokyo, and the number of very hot days (Tmax>35°C) in the city is now considerable.
2) There is a significant trend (since 2014) towards higher Tokyo JAS relative humidity (between +5~10%).
3) There is increased variability in Tokyo JAS precipitation with statistical evidence that nighttime rainfall is more pronounced.
4) There is a gradual increase in Tokyo JAS cloud cover in the last 56 years (~+4%) with instances of anomalously *high* values more frequent in the last 15 years.
5) There is a slight but not significant decrease in Tokyo JAS wind speed.

The question for the current research is how do these observed changes affect the suitability of Tokyo as a summer destination for tourists as measured by the HCI:Urban? With reference to equation (2) we can understand that increases in air temperature and relative humidity (i.e. the thermal component) will tend to lower the HCI value and decrease climatic favorability to tourism. Similarly, increases in the physical attributes of cloud cover and rainfall will also tend to reduce the value of the index. Due to the small scale of change in wind speed, its limited contribution (10%) to the HCI:Urban, and the wind HCI rating system (see Table 2), changes in wind speed will have little impact on the HCI composite value.

5.2 Tokyo JAS Holiday Climate Index (HCI:Urban) 1964–2019

Given the longitudinal changes in the HCI:Urban meteorological variables (described in 5.1 above) it is unsurprising that on a decade-by-decade basis there has been a steady decline in the Tokyo JAS HCI:Urban and thus the suitability of the city to summertime tourism over the period 1964-2019. As measured by the $HCI{:}Urban_{24}$ conditions deteriorated from upper 'marginal' (HCI=47) in the 1960s to 'unacceptable' (HCI=38.1) in the 2010s. Over the same period the $HCI{:}Urban_{16}$ declined from 'acceptable' in the 1960s (HCI=50.2) to 'marginal' (41.8) in the 2010s (Table 7). According to the respective linear regression equations the current (2020) values are $HCI{:}Urban_{24}$=38.2 and $HCI{:}Urban_{16}$=42.1. Thus the precipitation in the 8 hours between 10pm and 6am causes the 16-hour

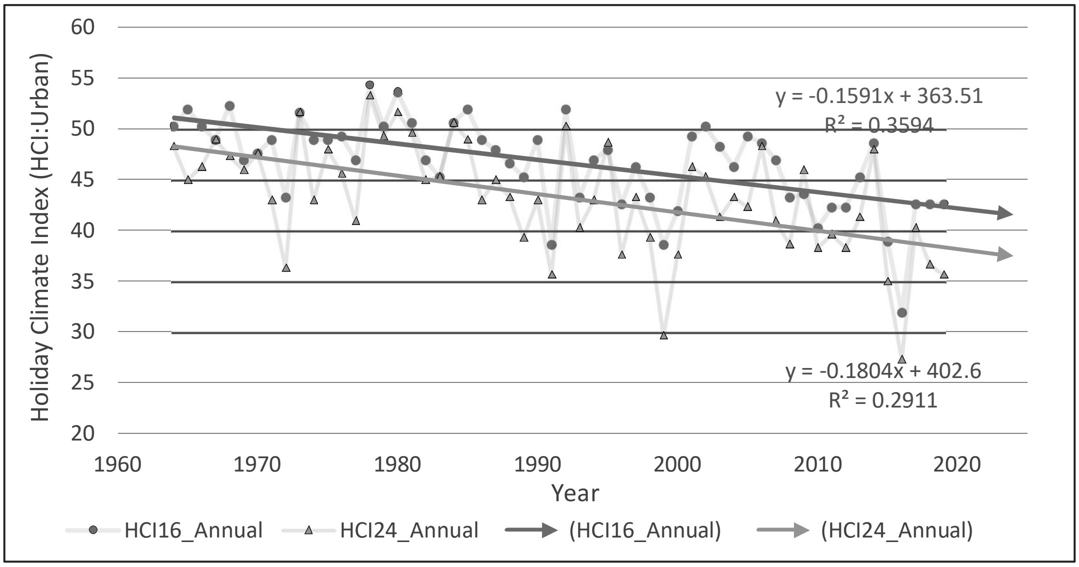
HCI composite to rate the tourism climate as ‘marginal’ while the HCI_{24}, which includes hours when tourists are generally inactive, as ‘unacceptable’. Being 3.9 HCI points above the 24-hour HCI the HCI:$Urban_{16}$ rates the tourism climate more positively which could have important implications for tourism policy and planning in Tokyo.

Table 7. Tokyo JAS HCI:Urban 1964-2019 (by decade)

	1960s (1964-69)	1970–79	1980–89	1990–99	2000-09	2010-19	2020 (est)
HCI:$Urban_{24}$	47	45.9	46.2	41.1	43	38.1	38.2
HCI:$Urban_{16}$	50.2	49.1	48.8	44.9	46.8	41.8	42.1

Figure 7 shows the annual change in Tokyo’s JAS HCI:$Urban_{16}$ (upper line) and HCI:$Urban_{24}$ (lower line). Within a pattern of year-to year variability, both indices show a gradual decline in the incidence of ‘acceptable’ years (HCI>50) and an increase in the incidence of years when tourism can be considered ‘unacceptable’ (HCI<40). A point of bifurcation in the data appears to be the 1990s before which both indices indicate years in each decade when Tokyo’s climate was ‘acceptable’ for tourism. However, in the last 10 years significant increases in the incidence of ‘unacceptable’ years are apparent (for example, the HCI:$Urban_{24}$ indicates 7 different years of HCI<40 during the 2010s). The trend towards less suitable climatic conditions for tourism in Tokyo is perhaps best exampled however by the fact that both indices show the most suitable three years for tourism in Tokyo (1968, 1978, and 1980) were all more than 40 years ago.

Figure 7. Tokyo JAS HCI:Urban by year (1964-2019)



To complement the time-series record of the two indices described in figure 7, figures 8a and 8b show the distribution of HCI ratings ('good', 'acceptable', 'marginal' and 'unacceptable') for JAS months in each decade for both indices. The decline in 'good' and 'acceptable' months from 20-30% (HCI:Urban$_{24}$) and 40-50% (HCI:Urban$_{16}$) in the 1960s and 1970s to less than 10% in the 2010s for both indices is noteworthy. At the same time there has been a significant shift in the frequency of 'unacceptable' months increasing from 10-20% (HCI:Urban$_{24}$) and 0-5% (HCI:Urban$_{16}$) in the 1960s and 1970s to 30-40% of months for both indices in the 2010s. Interestingly, in both indices the ratio of 'marginal' months (50-60%) is relatively unchanged throughout the 56-year period.

Figure 8. Rating of JAS months in Tokyo by decade

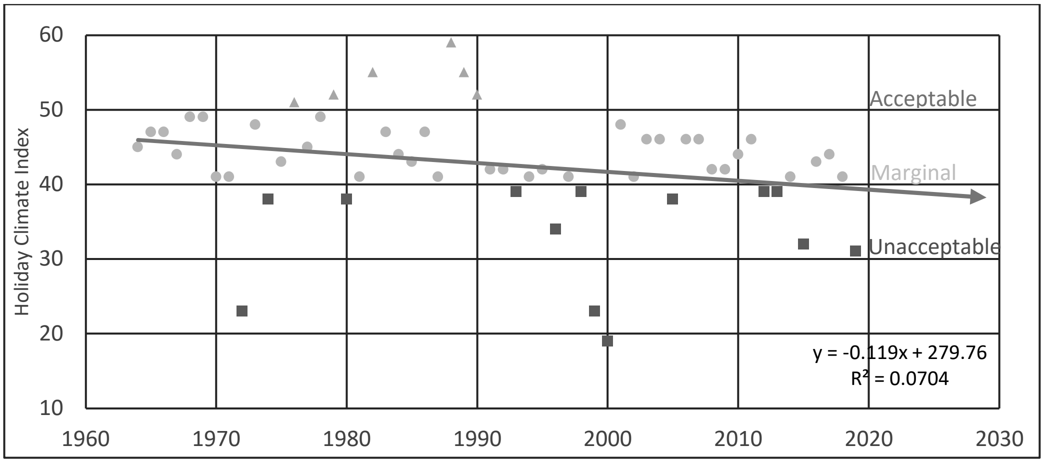
(8a). HCI:Urban$_{24}$ (8b) HCI:Urban$_{16}$

While both indices indicate a decline in the favorability of Tokyo JAS tourism the HCI:Urban$_{16}$, by omitting physical nighttime conditions, provides a slightly more positive overall rating of 3-4 points. To examine these trends on a scale more appropriate to individual tourist visits to Tokyo, the following section examines the HCI:Urban values for both indices for each of the three summer months (July, August and September) individually.

5.2.1 July (HCI:Urban$_{24}$)

Figure 9a shows the July HCI:Urban$_{24}$ for the years 1964 to 2019. The long-term linear trend (y= -0.119x) indicates a decline in the favorability of Tokyo's July climate to tourism of approximately -1 HCI point per 8 years. As the relatively low R^2 value suggests there is great variability about this rate of decline. For example, despite 70% of Julys in the 1960s, 1970s and 1980 being rated as 'marginal' (HCI=40-49) at the same time there were 6 'acceptable' years (HCI=50-59) in the 1970s and 1980s. The decline is shown clearly by the increased number of 'unacceptable' years (HCI<40) in the period after the 1990s (10 in total). Linear regression indicates 'unacceptable' (HCI:Urban$_{24}$=39.4) tourism climate conditions in 2020.

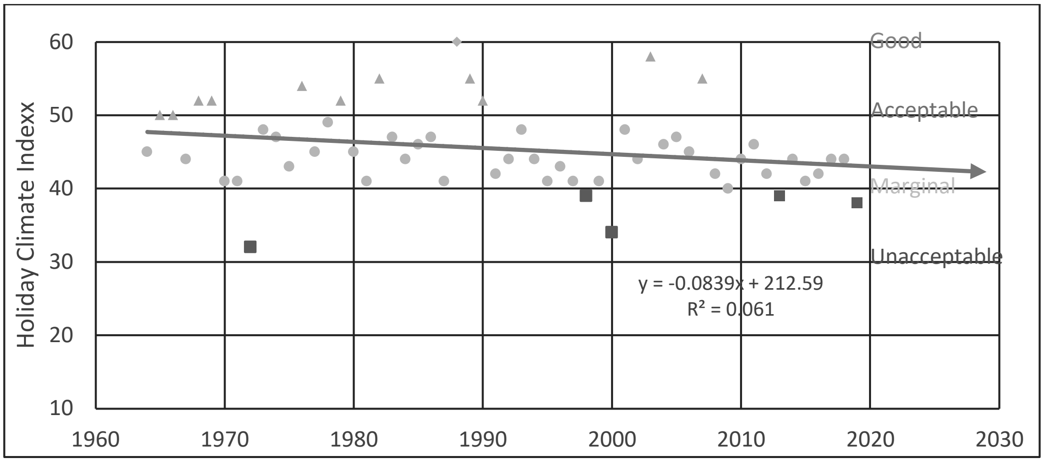
Figure 9a. Tokyo HCI:Urban24 (July)



5.2.2 July (HCI:Urban16)

The HCI:Urban16 (figure 9b) shows a similar decline to the HCI:Urban24, but with a shallower rate of decline (y=-0.0839x) i.e. -1 HCI point per 12 years. In the 1960s, 70s and 80s, 35% of Julys were rated as "acceptable" or "good" (c/f with HCI:Urban24). By contrast, between 1990 and 2019 there were only two instances of 'acceptable' July conditions and four cases of 'unacceptable' ones; most years were 'marginal'. Linear regression indicates 'marginal' (HCI:Urban16=43.1) tourism climate conditions in 2020.

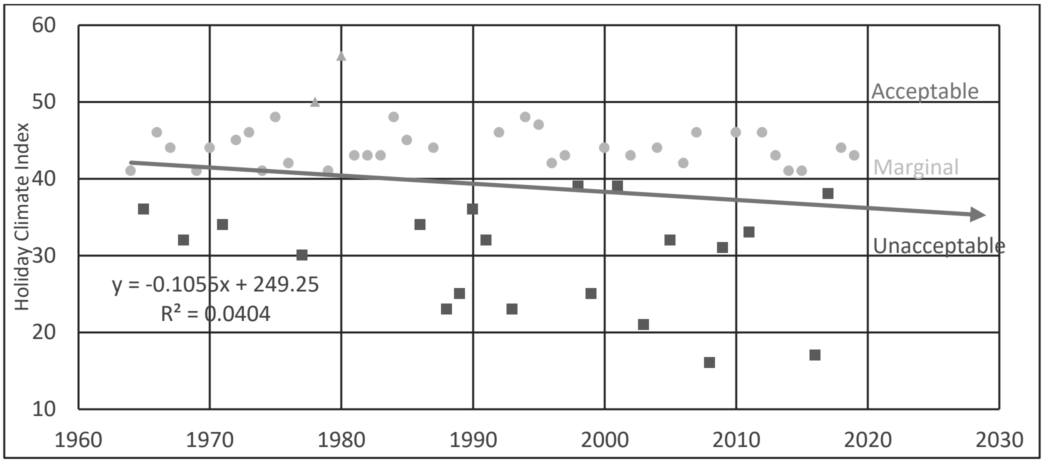
Figure 9b. Tokyo HCI:Urban16 (July)



5.3.1 August (HCI:Urban24)

Figure 10a describes the HCI:Urban24 for August 1964-2019. Historically, August experiences the highest temperatures and humidity of the three JAS months and this is reflected in the 7:4 ratio in ‘marginal’ (34 cases) to ‘unacceptable’ years (20 cases) – two further years were rated ‘acceptable’. August shows a decline in favorability over time of about -1HCI point per 10 years (y= -0.1055x) with the transition from ‘marginal’ to ‘unacceptable’ tourism conditions taking place in the mid-1980s. Despite this decline, the frequency of ‘marginal’ Julys (HCI=40-49) has remained constant at 5-7 instances per decade. By contrast ‘severely unacceptable’ years (HCI<30) have increased significantly with seven such years since 1988 including 2003 (HCI=21), 2008 (=16), and 2016 (=17). Linear regression indicates ‘unacceptable’ (HCI:Urban$_{24}$=36.1) tourism climate conditions in 2020.

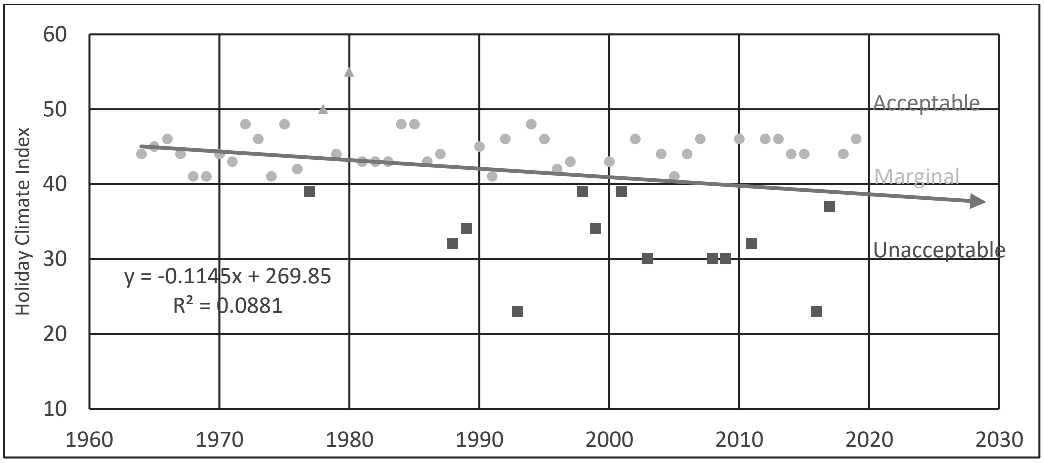
Figure 10a. Tokyo HCI:Urban$_{24}$ (August)



5.3.2 August (HCI:Urban$_{16}$)

The HCI:Urban$_{16}$ August (Figure 10b) exhibits a very similar rate of decline (y= -0.1145x) to its 24-hour counterpart but with the transition from ‘marginal’ to ‘unacceptable’ conditions placed in the mid-2000s. The ratio of ‘marginal’ to ‘unacceptable’ years (3:1) is also higher. In accordance with the 24-hour record, despite the overall decline in conditions ‘marginal’ years dominate each decade, and just two Augusts (1993 and 2016) were rated as ‘severely unacceptable’ (HCI<30) to tourism while the HCI:Urban$_{24}$ rated seven Augusts as such. From this we can see the powerful impact of the average 3 or 4 HCI points attributed to the HCI:Urban$_{16}$ on the overall interpretation of conditions. The linear regression-generated HCI:Urban$_{16}$ of 38.6 indicates ‘unacceptable’ conditions in 2020.

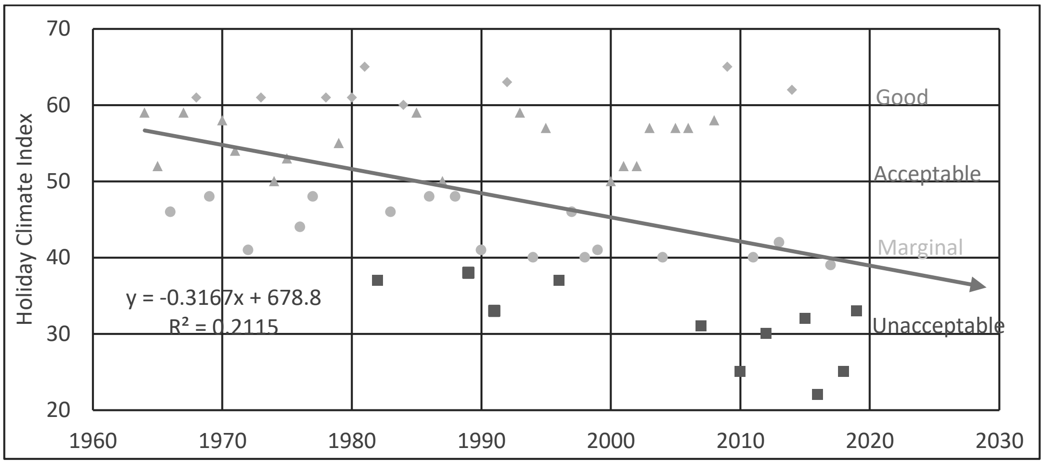
Figure 10b. HCI:Urban$_{16}$ (August)



5.4.1. September (HCI:Urban$_{24}$)

According to the analysis September is the most comfortable of the three JAS months with a significant number of years deemed 'acceptable' or 'good' for tourism (62% of Septembers between 1964 and 1989). September however shows the sharpest decline (y= -0.3167x) in JAS HCI rating over the 56-year period (figure 11a). This manifest itself in two ways: a decline in the share of benign conditions for tourism (i.e. 'good' or 'acceptable') and a concomitant increase in 'unacceptable' years apparent in the 2010s. Linear regression indicates 'unacceptable' (HCI:Urban$_{24}$ = 39.1) tourism conditions in 2020.

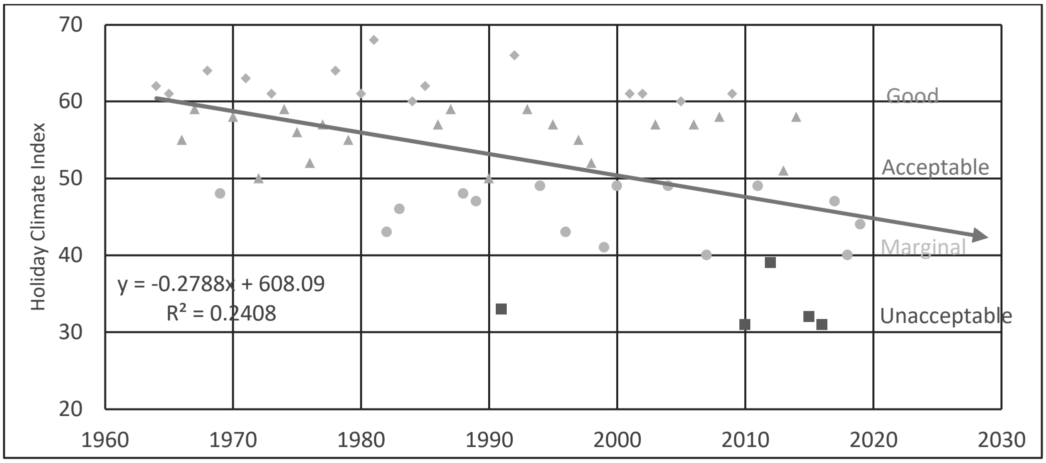
Figure 11a. HCI:Urban$_{24}$ (September)



5.4.2 September (HCI:Urban$_{16}$)

The rate of decline in the HCI:Urban$_{16}$ for September (y= -0.2788x) is less steep than the 24-hour counterpart but still represents a rate more than twice that of July and August (figure 11b). The decline in 'good' or 'acceptable' conditions from 81% of Septembers in the 1960s, 1970s and 1980s to 50% in the 1990-2019 period exemplifies this. Although four instances of 'unacceptable' September tourism conditions have occurred in the 2010s, linear regression of the 16-hour index indicates 'marginal' conditions (HCI:Urban$_{16}$ = 44.9) in 2020.

Figure 11b. HCI:Urban$_{16}$ (September)



6. Discussion

Climatic conditions have a strong bearing on the quality of the tourist experience (Rutty & Scott, 2010), thus for a relatively newly established tourist megacity like Tokyo with considerable investment in tourism, a better understanding of the suitability of its climate to tourism is of great importance. Evidence from the current research shows that Tokyo's summertime climate has transitioned from 'acceptable/marginal' (HCI:Urban$_{24}$ = 48.3) across the three JAS months in 1964 just after the Tourism Basic Law came into force to 'unacceptable' *in* all three JAS months in 2019 (HCI:Urban$_{24}$=38.4). Although August shows the lowest favorability to tourism in 2019 (HCI$_{24}$=36.2) September shows the most dramatic change over the 56-year period. Thus September's 'acceptable' rating (HCI:Urban$_{24}$ = 56.8) in 1964 has declined rapidly to 'unacceptable' (HCI:Urban$_{24}$ = 39.4) in 2019 with the month now indistinguishable from July and August in terms of the favorability of its climate resource (Table 8).

If we adopt the HCI:Urban$_{16}$ however some important differences can be observed. It is natural that the HCI:Urban$_{16}$ should deliver a higher HCI:Urban value since it omits rainfall in the hours between 10pm and 6am. This is an important distinction to make since the climatic conditions during times when tourists are less active have been shown to have limited impact on tourist activity (Steiger, Abegg and Janicke, 2016). In adopting the HCI:Urban$_{16}$ although the longitudinal trend of decline in climate favorability remains, the index delivers a more favorable HCI score (typically 3-4 HCI points above the HCI:Urban$_{24}$) and this can recalibrate the 'rating' of tourism climate conditions. Thus in September 1964 the HCI:Urban$_{16}$ rated Tokyo's climate resource as 'good' (HCI:Urban$_{16}$ = 60.5) rather than 'acceptable' as the HCI:Urban$_{24}$ does. Similarly in 2019 the HCI:Urban$_{16}$ rates Tokyo's climate resource in both July and September as 'marginal' one rating above the 'unacceptable' rating delivered by the HCI:Urban$_{24}$ (Table 8). One cause may be the additional annual increase in nighttime rainfall estimated in the current research as 0.94mm per annum. The issue of daytime/nighttime rainfall discrepancies and their impact on in situ tourist activity requires further research.

Table 8. Holiday Climate Index Urban 1964 and 2019 (by month)

	Year	July	August	Sept	JAS Total
HCI:Urban$_{24}$	1964	46.0 (M)	42.0 (M)	56.8 (A)	48.3 (M)
	2019	39.5 (U)	36.2 (U)	39.4 (U)	38.4 (U)
HCI:Urban$_{16}$	1964	47.8 (M)	45.0 (M)	60.5 (G)	51.0 (A)
	2019	43.2 (M)	38.7 (U)	45.2 (M)	42.3 (M)

Note: G= 'good'; A = 'acceptable'; M= 'marginal'; U= 'unacceptable'

The decline in the favorability of tourism climatic conditions in Tokyo described here concurs with studies in other tourist settings around the world (Damm et al., 2017; Grillakis et al., 2016; Kubokawa et al., 2014; Rutty et al., 2020, Rutty et al., 2010), and mirrors the findings of the IPCC AR4 (IPCC, 2018). Despite increasing public awareness and political initiatives to tackle global heating in Japan and beyond, atmospheric CO_2 concentration is accelerating more rapidly by the decade (NOAA, 2020) making it more likely that the suitability of Tokyo's tourism climate conditions will deteriorate further in years to come. Of the 5 meteorological variables that make up the HCI:Urban, thermal comfort, that is temperature and relative humidity, is the Achilles heel for tourists visiting Tokyo in JAS. The current research clearly shows that both extreme temperatures and higher humidity are becoming more frequent in the city. Not only have air temperatures increased by around 1^{o}C since Tokyo last hosted the Olympic Games in 1964 but there is evidence of increased humidity of up to 10 percentage points in the last 6 years. Tokyo's September tourism climate resource has seen the most significant changes.

These findings will have important implications for the favorability of summertime tourism in Tokyo in terms of tourists' health and the viability of tourism businesses themselves. If Tokyo is to satisfy the travel demand to visit the city after the Covid-19 imposed travel restrictions have been lifted it will need adaptation and coping strategies to combat heat stress disorder issues as much as it needs strategies to deal with tourism in the post-pandemic world. Climate-related policy will need to respond by considering *in situ* solutions such as increased provision of indoor tourism activities, or material changes to the urban fabric of the city such as rest spaces for poorly acclimated visitors (Kasai et al., 2017; Ohashi et al., 2015). Nudging of tourist behavior by providing infrastructure that can be utilized regardless of summertime thermal conditions should also be adopted. A strategy to temporally discourage tourists from visiting during JAS and consider ‘shoulder’ seasons in Spring and Autumn might also be effective (Kubokawa et al., 2014). Promoting shoulder season visitation will however be difficult without significant changes to the constraints imposed by institutional seasonality such as school and employee holiday entitlement. Moreover, the seasonal bias inherent in the marketing of travel and tourism products will need new innovation (Rutty & Scott, 2010). Such initiatives will require a broad consensus both domestically and internationally that is probably beyond the ability of a city even the size of Tokyo to undertake. Cooperation between stakeholders at the local, regional, and pan-continental scales is thus vital (Gilliakis et al., 2017). Temporal nudging was adopted relatively successfully by Amsterdam in 2018 to reduce overcrowding (Silva, 2019), and if a similarly strategic approach can be adopted to address Tokyo JAS visits during the most heat stressed time of year it might help to reduce the exposure and vulnerability of visitors, particularly those who are less well-acclimated to Tokyo’s extreme summertime heat and humidity.

The differences between well-acclimated and less well-acclimated visitors is an important issue that needs to be understood better if JAS climate is to inform Tokyo’s policy towards summertime visitors (Garrett, Kingman, Sluijter et al., 2019). Tourists desire climatic condition that are most ideal with respect to their country of origin (Demiroglu, Akbas, Turp et al., 2018) and as studies in Malaysia and Taiwan (Makaremi, Salleh, Jaafar et al., 2012; Lin & Matzarakis, 2011) indicate there are innate differences in the way people of different climatic origins experience thermal comfort. Thus to create a bespoke thermal environment for visitors, policy should consider the degree of acclimatization between say, visitors from South East Asia who are more accustomed to Tokyo JAS-like conditions and Northern European visitors who are not. This may help to reduce vulnerability to heat stress disorder among tourists and direct them to thermally appropriate tourist activities. A survey of international visitors to Tokyo in 2019 by the Ministry of Land Infrastructure, Transport and Tourism which reported a higher incidence of ‘extreme heat’ sensation among Europeans than South east Asian visitors supports this notion (MLIT, 2019).

7. Towards an HCI:Urban for Japan

Despite the utility of employing the urban-specific HCI:Urban to explore urban tourism climate in Tokyo and the more tourist activity-centric HCI:Urban$_{16}$ piloted here, there appear to be some circumstances under which the index does not represent conditions well. The idea that there is no single index for tourism has been indicated in previous research (Scott, Hall & Gossling, 2012) and the results here suggest an index to represent Tokyo and similar sub-tropical urban environments might be necessary. This supports the work of Kubokawa et al. (2014) who propose research into developing a tourism climate index specifically for Japan. With this in mind, based on the current research three suggestions for tailoring a HCI:Urban for Tokyo are outlined below.

The first proposal is the adoption of the HCI:Urban$_{16}$ piloted here. Modifying existing indices is a common practice (Scott, Rutty, Amelung and Tang, 2016) and as shown in 5.2 above can help in providing a more thorough picture of the climate resource over time as experienced by the tourists. By recalibrating the HCI value the 16-hour hybrid can also form a stronger foundation for policymakers and decision makers who aim to use such data to provide a better experience for all tourism stakeholders. As a hybrid of the HCI:Urban the HCI:Urban$_{16}$ still needs to be empirically tested but would on initial appearance be a suitable way to consider summertime climate favorability in a city like Tokyo.

The second proposal is reconsideration of the thermal comfort sub-index. The key failing of the HCI:Urban thermal comfort rating is not in the weighting of 40% but in its inability to differentiate days when Humidex values rise above 39C ('great discomfort'). More than 2/3 of Tokyo JAS days in the period 2010-2019 were at, or above, Humidex 39C (8% exceeded Humidex 50C when 'extreme danger of heatstroke' is likely), and so modifying the index seems to be a priority. Interestingly, when MLIT research into visitors' perceptions of Tokyo's summertime climate in late August 2019 (MLIT, 2019) found that 93% of all visitors considered the city too 'hot and humid' to walk outside, the Humidex value was 44^{o} - the median Tokyo JAS value in the 2010s. The 93% may thus be an underestimate of visitor perception of Tokyo summer climatic conditions. A scale of negative weightings for extremely high Humidex values seems an appropriate modification to the HCI's thermal component and should be investigated. The use of proxy data concerning heat stress patients among residents as modeled by Kasai et al. (2017) might be one possible approach to understand the dangers of such conditions.

The third proposal is for a reconsideration of the rating for the physical facets of rainfall and wind speed. The HCI:Urban is a considerable improvement on the TCI as it internalizes heavy rain events typical of Tokyo's sub-tropical conditions by using a penalty rating (-1) for rainfall in excess of 25mm per day. However, the index does not differentiate between days in which 25mm of precipitation falls in one hour, and those when 2.5mm of rain falls for 10 hours. There is compelling evidence that Tokyo JAS rainfall is becoming more tropical in nature with short, sudden bursts of heavy rainfall (*geriragouu*) the norm rather than steady prolonged lighter rainfall (Tsuji, Yokoyama and Takayabu, 2020). If we consider the negative impact on outdoor tourist activity under these two scenarios it seems clear that a day with just one hour of very heavy rain should be rated differently to a day of steady, persistent rain. A more sensitive rainfall rating scheme which can internalize both the duration and volume of precipitation over a certain threshold is thus a suggestion for future research.

Finally, HCI:Urban wind ratings as proposed under Rutty, Scott et al. (2020) may also be unsuitable for Tokyo JAS conditions. Based on average daily wind speed the current research found no instances of a rating lower than 8. Thus for days where the HCI:Urban composite total is only 30, wind might account for more than 1/3 of a tourist's total experience of weather conditions. By contrast the wind rating scheme such as employed by the TCI rates the wind types according to air temperature and may be more appropriate for examining Tokyo's JAS tourism climate profile.

8. Conclusion

Tourism has become a key component of the socioeconomic portfolio of Tokyo and as a result a better understanding of contemporary climate conditions as they pertain to tourism and tourists is urgently needed. It is hoped that this exploratory research can act as an impetus for such understanding through more tourism biometeorological research in cities where climate resources are undergoing change.

A range of studies indicate climate change will present challenges for tourism and may cause tourist activities to be become more marginal or cease altogether (Scott, Hall, and Gossling, 2019; Grillakis et al., 2016; Damm et al., 2017; Rutty and Scott, 2010). As a means to quantify the suitability of climate for tourism and tourists the HCI:Urban and the HCI:Urban$_{16}$ modification present a holistic picture of tourist climate and can be tools to help understand where and when these challenges might arise and provide some indicators about which adaptation strategies should be implemented. As the discussion here indicates adaptation may be temporal and spatial, but will also need to be flexible enough to deal with the greater climate variability expected in the future.

The results obtained here should be seen in light of the limitations of the study. The principal limitation is the use of the Canadian Humidex to calculate thermal comfort. Though used in several prominent studies of tourism biometeorology (Rutty et al., 2020; Scott et al., 2016), Humidex has been found to be less sensitive to human thermal comfort than other metrics such as Physiological Effective Temperature (PET) (Zare, Hasheminejad, Shirvan et al., 2018; Heo and Bell, 2019), and thus may not reflect the true thermal comfort of visitors. A second limitation is the drawing of conclusions from daily data aggregated into monthly form. This was necessary to expedite analysis of the large volumes of data generated by the extended longitudinal record (56 years) while using relatively simple tools of analysis (Microsoft Excel). To overcome this more advanced powerful tools such as the Ray-man software

(Matzarakis and Rutz, 2007) should be considered for future studies. At the same time, an approach which uses 10-day meteorological data means may offer greater accuracy and offer assessment at temporal scales more appropriate to tourists themselves. Finally, the use of data from just one weather station can only give us an estimate of the conditions at each location visited by tourists in Tokyo. Unfortunately, publicly available data from weather stations such as Edogawa Rinkai (near Tokyo Disneyland) provides only limited meteorological coverage and could not be included in the current research.

In wake of the Covid-19 pandemic, health and safety have become the predominant concerns in human interactions including the act of tourism. As a physical attribute directly affecting tourists' experience of, and well-being at, a destination, weather, climate and climate change not only impacts tourists' health but - like Covid-19 - can also impact places where tourism is a significant economic activity. A better understanding of the tourism climate through focused research that uses tourism climate tools such as the HCI:Urban is essential if urban centers like Tokyo are to sustain their international tourism profiles as global heating progresses.

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東京における Tourism Holiday Index (HCI:Urban)の適性の研究

David Williams

【要旨】

観光客の訪問先決定に際して、観光地における気候は極めて重大な役割を果たす。即ち、観光業は観光地の気候に大きく左右される産業なのだ。気候変動が科学的に証明されていることを考慮すると、将来的に気候が観光客のあり方、観光業自体に大きな負の影響を与える可能性は高い。東京は観光インフラに莫大な投資を行ってきた都市であるが、夏季は厳しい暑さが続くことを考えると、気候変動によって観光が危険かつ困難になる恐れもある。以上の理由により、東京における観光資源としての気候に対する理解は必要不可欠なものである。本研究では、HCI を用いて 1964 年から 2019 年の期間における長期的な観光資源としての気候を調査した。この期間に渡っては、夏季 3 ヶ月間における気候の変動性の増大及び観光学的な視点から見る気候条件の悪化が認められている。このように日本に独自な状況を正確に表すためには、観光資源としての気候を表すための新しい指数が必要である。

キーワード：Holiday Climate Index、気候変動、都市観光、観光資源としての気候