Using a 'tourism climate index' to examine the implications of climate change for climate as a tourism resource

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Abstract

Climate has a strong influence on the tourism and recreation sector and in some regions represents the natural resource on which the tourism industry is predicated. There has been little consideration of how climate change might affect the tourism climate resource or how such changes could alter the competitive relationships between tourism destinations. This study used a modified version of Mieczkowski's (1985) 'tourism climate index' (TCI) to explore the impact of projected climate change on the tourism climate resource of a sample of tourism destinations in North America. Conceptual seasonal tourism climate distributions are defined and the current tourism climate index scores of 17 North American cities calculated. All Canadian cities had a 'summer-peak' distribution. Cities in the southern US displayed either a 'winter-peak' or bimodal spring-autumn peak distribution. Los Angeles was the only city examined to approximate a year-round optimal tourism climate distribution. Seasonal tourism climate index scores are then compared with seasonal accommodation costs at five locations, in order to determine whether the tourism climate index reflects tourism demand. Results at each location were positive. Climate change scenarios were constructed from two general circulation models (CGCM2 and HadCM2) for the 2050s and 2080s and integrated into the tourism climate index of eight Canadian cities. The cumulative annual TCI score improved for all of the cities. Seasonally, the impact of climate change varied by location. Seasonal TCI rating improved in each season for cities in western Canada (Calgary, Vancouver and Yellowknife), while the TCI rating declined in the key summer tourism months of July and August in eastern Canada (Toronto and Montreal). As the first empirical assessment of the implications of climate change for the tourism climate resource, this investigation also raises questions for future inquiry.

Keywords Tourism Climate Index, Climate Change, Tourism

Introduction

Tourism is a major sector of the global economy, with international tourism receipts of US$439 billion in 1998 (World Tourism Organization 1999). It is projected that by 2020, there will be 1.6 billion international tourist arrivals, spending over US$2 trillion worldwide (World Tourism Organization 1998). Canada and the United States were among the top 10 tourism destinations in

1998, in terms of international tourist arrivals and related economic receipts. Domestic tourism in both nations is estimated to be many times larger in terms of economic activity.

Climate has a strong influence on the tourism and recreation sector and in some regions of the world constitutes the resource on which the tourism sector is predicated. Inter-annual climate variability influences the length and quality of recreation seasons and the profitability of the tourism industry. In Canada Wilton and Wirjanto (1998) estimated that a 1^0C above normal summer temperature increases domestic tourism expenditures by approximately 4%. Studies by Agnew (1995) and Benson (1996) in the UK also found that tourism spending was partially determined by climatic conditions. In both analyses, tourism spending abroad increased following a cold winter. Benson (1996) and Giles and Perry (1998) also found that domestic tourism spending in the UK increased during and following a warm summer.

Yet despite the importance of climate to tourism, Smith (1993:389) indicated that, "There have been comparatively few investigations into the relationships between climate and tourism." Consequently, the vulnerability of the tourism sector to current climate variability and long-term climate change has not been adequately assessed.

The tourism climate index (TCI) was originally conceptualized by Mieczkowski (1985) as a composite measure that would systematically assess the climatic elements most relevant to the quality of the tourism experience for the 'average' tourist (i.e., the most common tourism activity of sight-seeing and shopping). The TCI developed by Mieczkowski (1985) was based on previous research related to climate classifications for tourism and recreation (Heurtier 1968, Crowe 1976) and theoretical considerations from the biometeorological literature related to human comfort, particularly with reference to tourism activities (Burnet 1963, Dammann 1964, Hofer 1967, Heurtier 1968, Danilova 1973, and Kandror et al. 1974). Initially, 12 monthly climate variables were identified from the literature as pertinent to the TCI. Meteorological data limitations reduced number of climate variables that were integrated into the TCI to seven (monthly means for maximum daily temperature, mean daily temperature, minimum daily relative humidity, mean daily relative humidity, total precipitation, total hours of sunshine, and average wind speed). These seven climate variables were combined into five sub-indices that comprised the TCI. A standardized rating system, ranging from 5 (optional) to -3 (extremely unfavourable), was devised to provide a common basis of measurement for each of the sub-indices. The five sub-indices and their relative contribution to the TCI are outlined in Table 1. Although devised on the basis of available biometeorological literature, the rating systems of the five sub-indices and their relative weightings within the TCI are ultimately subjective. The biometeorological literature, upon which the weighting of the five climatic variables that comprise the TCI and the thresholds used to devise the rating systems for each of the five variables, has been described at length in Mieczkowski (1985) and the reader is referred to the original paper for additional details pertaining to the conceptual and methodological development of the TCI.

Table 1 Sub-indices within the tourism climate index

Sub-Index	**Monthly Climate Variables**	**Influence on TCI**	**Weighting in TCI**
Daytime Comfort Index (CID)	maximum daily temperature & minimum daily relative humidity	Represents thermal comfort when maximum tourist activity occurs	40%
Daily Comfort Index (CIA)	mean daily temperature & mean daily relative humidity	represents thermal comfort over the full 24 hour period, including sleeping hours	10%
Precipitation (P)	total precipitation	reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	total hours of sunshine	rated as positive for tourism, but acknowledged can be negative because of the risk of sunburn and added discomfort on hot days	20%
Wind (W)	average wind speed	variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while ‘wind chill’ in cold climates rated negatively)	10%

The TCI provides a method to systematically rate the tourism climate resource for locations around the world, using an easily interpretable scale (-20 to 100) that is divided into 11 categories, where 50-59 is ‘acceptable’ as a tourism climate, 80-89 is ‘excellent,’ and 90-100 is ‘ideal.’ Though not designed for climate change research, the TCI also represents a potentially useful empirical tool for exploring the impact of climate change on the tourism climate resource.

The purpose of this paper is to investigate the relationship between climate and tourism by using a modified version of the tourism climatic index developed by Mieczkowski (1985) to explore the spatial and temporal patterns of the tourism climate resource in North America. The study will also attempt to validate the TCI in the tourism marketplace and examine how climate change scenarios may impact the tourism climate resource in Canada.

Methods

Study Sites and Data

A total of 17 cities were selected for this study (Table 2), roughly forming three latitudinal transects of North American (one across the US south, a second across the center of the US, and a third across southern Canada) and one longitudinal transect in western North America, extending from Denver in the south to Yellowknife in the north. For the Canadian cities all of the climate data are 30-year monthly normals for the period 1961-90 and were provided by the Meteorological Service of Canada. Climate data for the US cities were obtained from the National Climate Data Center of National Oceanic and Atmospheric Administration. Temperature and precipitation data were 30-year normals for 1961-90, while wind, relative humidity and sunshine were monthly averages for at least 20 years from the observed record. Sites with less than 20 years of climate data were removed from the analysis.

The climate change scenarios used in this analysis were obtained from the Canadian Climate Impact Scenarios (CCIS) project. The scenarios provided by CCIS (2001) have been constructed using recognized methodologies and in accordance with the recommendations of the Intergovernmental

Table 2 North American cities included in analysis of current TCI rating

Canadian Cities	Latitude	Longitude	**US Cities**	Latitude	Longitude
Vancouver	49.25^{0}N	123^{0}W	Seattle	47.5^{0}N	122.25^{0}W
Calgary	51^{0} N	114^{0}W	Los Angeles	34^{0}N	118^{0}W
Edmonton	53.5^{0} N	113.5^{0}W	Phoenix	33.5^{0}N	112^{0}W
Yellowknife	62^{0} N	114^{0}W	Denver	39.75^{0}N	105^{0}W
Winnipeg	50^{0} N	97.5^{0}W	St. Louis	38.75^{0}N	90.25^{0}W
Toronto	43.75^{0} N	79.5^{0}W	New Orleans	30^{0}N	90^{0}W
Montreal	45.5^{0} N	73.5^{0}W	Miami	25.75^{0}N	80.25^{0}W
Summerside (PEI)	46^{0} N	64^{0}W	Charleston	32.75^{0}N	80^{0}W
			New York	40.5^{0}N	74^{0}W

Panel on Climate Change's (IPCC) Task Group on Scenarios for Climate Impact Assessment (TGCIA). The scenarios available from CCIS are derived from climate change experiments undertaken at six international climate modeling centers that meet the criteria established by TGCIA. The scenarios are derived from 30-year means (2040 – 2069 to the 2050s scenario and 2070 – 2099 to the 2080s scenario) and represent change with respect to the 1961-1990 base-line period. The wide range of variables required for this analysis restricted the use of scenarios to the greenhouse gas plus aerosol runs from the Canadian Centre for Climatic Modelling and Analysis (CGCM2) and the UK Hadley Centre (HadCM2). In both cases, ensemble scenarios were used (gax). The HadCM2 scenarios represent the lower bounds of climate change projections in Canada (both 2050s and 2080s), while the CGCM2 scenarios represent the mid-range. The climate change scenarios are developed from the values of GCM grid boxes that are within 2.5° lat/long of the geocentroid of each city. The number of grid boxes included depends on the GCM resolution and to some extent on where the geocentroid lies within the grid box, but generally the change fields are calculated from the average of 4 to 6 GCM grid boxes. Table 3 indicates the annual temperature and precipitation change projections (2050s and 2080s) for the Canadian cities included in this study.

Data for a range of tourism demand indicators were sought to test the validity of the TCI in the tourism marketplace. Only hotel/resort accommodation rates were available at the temporal and spatial resolution required (monthly data for individual cities). Accommodation rates for randomly selected hotel/resorts covering different price ranges, but excluding those near airports and

Table 3 Annual climate change scenarios for Canadian cities

	CGCM2-gax				HadCM2-gax			
	2050s		2080s		2050s		2080s	
City	Tmean	Precip	Tmean	Precip	Tmean	Precip	Tmean	Precip
Vancouver	+2.3^{0}C	+4.0%	+3.6^{0}C	+8.8%	+2.5^{0}C	+5.6%	+3.6^{0}C	+7.1%
Calgary	+3.0^{0}C	+4.8%	+4.8^{0}C	+9.0%	+2.2^{0}C	+10.8%	+3.3^{0}C	+13.0%
Edmonton	+3.0^{0}C	+4.8%	+4.7^{0}C	+8.3%	+2.1^{0}C	+10.3%	+3.3^{0}C	+12.2%
Yellowknife	+3.3^{0}C	+0.1%	+5.3^{0}C	-0.6%	+2.5^{0}C	+5.7%	+4.0^{0}C	+6.0%
Winnipeg	+3.6^{0}C	+5.0%	+5.7^{0}C	+6.6%	+2.0^{0}C	+7.6%	+3.1^{0}C	+14.4%
Toronto	+3.1^{0}C	+1.5%	+4.9^{0}C	+4.8%	+1.5^{0}C	+7.3%	+2.4^{0}C	+17.9%
Montreal	+2.6^{0}C	+2.6%	+4.2^{0}C	+2.8%	+1.7^{0}C	+6.4%	+2.7^{0}C	+14.3%
Summerside (PEI)	+2.5^{0}C	+4.7%	+3.9^{0}C	+3.1%	+1.8^{0}C	+3.8%	+2.8^{0}C	+10.7%

downtown locations catering mainly to the business community, were obtained for six North American cities (Calgary, Toronto, Los Angeles, Miami, New Orleans and Charleston) that represented different tourism climate index distributions. Monthly accommodation rates were compiled from web sites and/or by telephone for hotels/resorts within or near to these cities.

Modification and Implementation of the TCI

The main modification to the original TCI in this analysis was the replacement of 'Effective Temperature' (ET) with a more recent 'Apparent Temperature' (Steadman 1984) or 'Heat Index' as it is referred to in applied use in the United States, as the measure of thermal comfort in the index. Although a range of other modifications were considered (see Discussion), the other difference relative to the original TCI analysis was related to the period of record for climate data. Though not specified, it is presumed that Mieczkowski (1985) used climate data or climate normals from 1951-80. The climate data used in this study are from the 1961-90 period. Both the rating systems for the five sub-indices and their weighting within the TCI were retained for this analysis.

Results

Current Tourism Climate Index Patterns

Theoretically, the tourism climate resource of every location can be classified into one of six annual TCI distributions (Figure 1). The spectrum runs from the 'optimal' year-round tourism climate

(TCI rating of 80 or above for each month of the year) through to a 'poor' year-round tourism climate (TCI rating under 40 throughout the year). The 'summer' and 'winter peak' curves have similar distributions, but are distinguished by the season in which the higher TCI scores occur. The 'summer peak' curve is indicative of many mid- to high-latitude locations where summer is the most pleasant period of the year for tourism. On the other hand, the 'winter peak' curve represents more equatorial and mid-latitude locations where cooler and/or lower humidity conditions in winter are more comfortable for tourists compared to hot and/or humid summer conditions. Where spring and fall periods are more acceptable to the tourist a 'bimodal' or 'shoulder peak' distribution is obtained. The tourism climate resource in regions with distinct wet and dry seasons will be determined to a large extent by precipitation. The TCI in these regions will display a dry season peak, when the climate in most conducive to tourism activity.

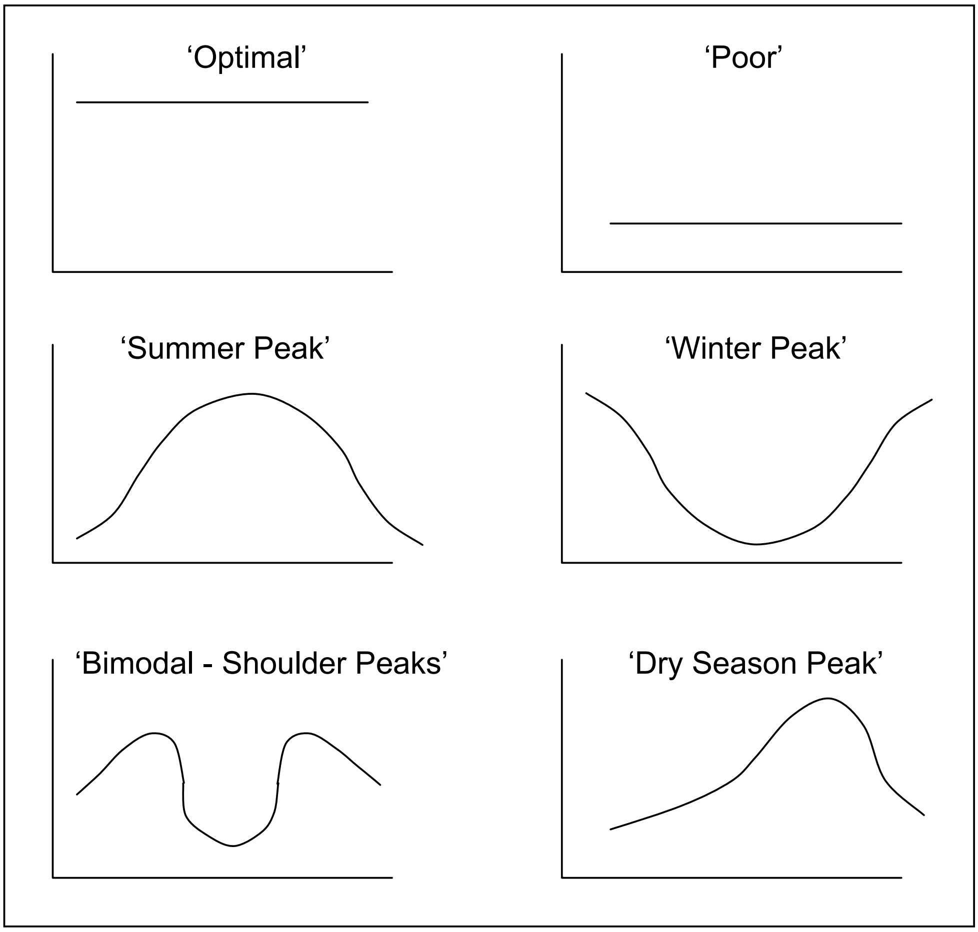

Fig. 1 Conceptual tourism climate distributions

Using the sample of 17 North American cities, four of the six conceptual TCI distributions were represented. All of the Canadian cities, regardless of latitude or coastal location, had a summer peak distribution (Figure 2 - Vancouver, Edmonton, Winnipeg and Toronto are not shown). Each of these locations has at least one month with a TCI score above 80, the level judged to be an 'excellent' tourism climate. The major difference in the TCI curves for these cities is the range of scores throughout the year. On the one hand, Yellowknife (lat 62^{0}N) is rated 'impossible' throughout the winter with TCI scores in the negative, while Calgary is only 'unfavourable' with TCI scores in the 30-39 range.

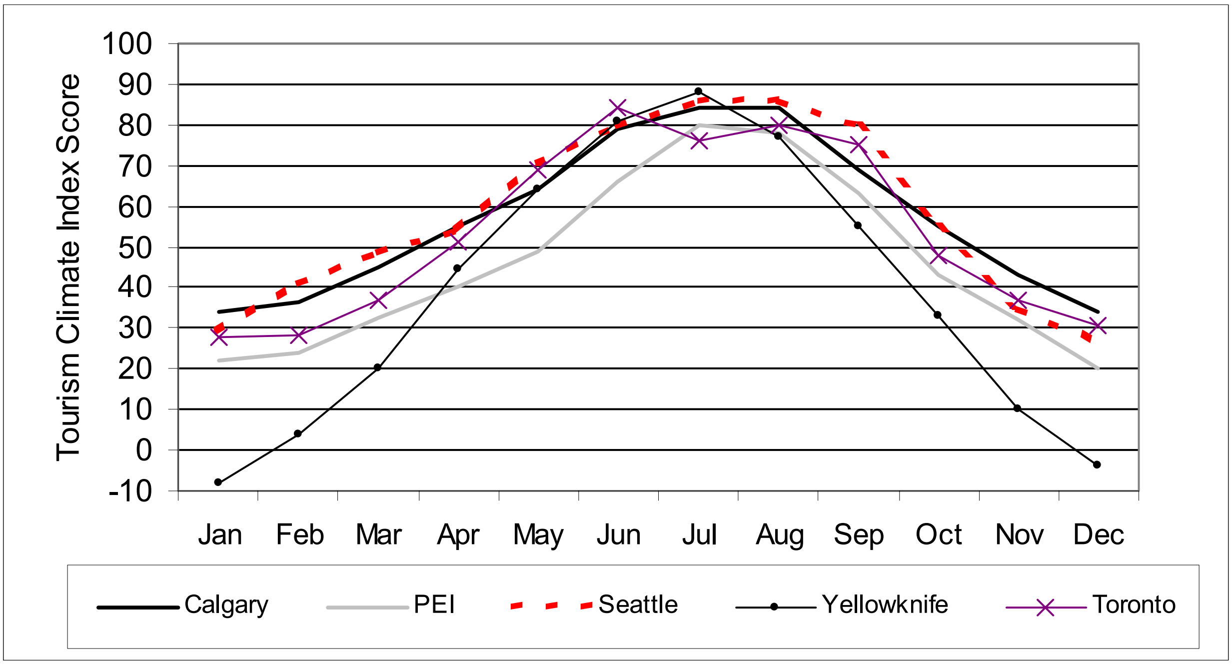

Fig. 2 Cities with summer peak TCI distribution

The TCI distributions in the US cities examined were much more varied. Like the aforementioned Canadian cities, Seattle and Denver displayed a summer peak (Seattle shown in Figure 2). Denver, like Toronto, had a slightly lower TCI in July than June and August, suggesting these cities are located in the transitional area between summer peak and bimodal-shoulder peak regions. The conceptual winter peak TCI distribution is represented by two popular North American winter tourism destinations, Phoenix and Miami (Figure 3). Both cities have six months with a TCI over 80 thereby classifying them as having 'excellent' tourism climates. Furthermore, Phoenix has an 'ideal' tourism climate (TCI scores of over 90) for half of the winter months. Summer TCI scores in Phoenix are lower because of the human discomfort caused by temperatures that often exceed

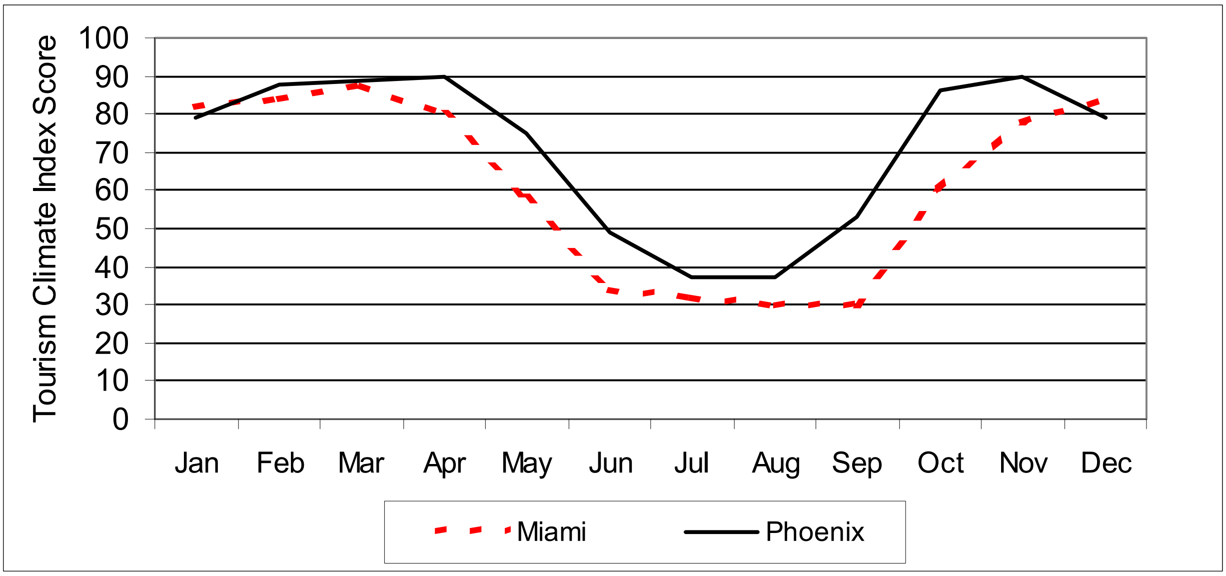

Fig. 3 Cities with winter peak TCI distribution

35^0C. On the other hand, the summer months in Miami have low TCI scores as a result of the combination of high temperatures and high humidity.

New Orleans, St. Louis, Charleston and New York, known for their pleasant spring and fall weather, represent the bimodal TCI curve (Figure 4). In these cities the heat and humidity make the summer climatically uncomfortable for the tourist while the winters are too cool. In contrast to the summer and winter peak regions, Charleston is the only city with a bimodal distribution to achieve a TCI score of 80. The 'optimal' curve is represented by Los Angeles, which has only two months below the 'excellent' TCI rating of 80 (Figure 5). The coastal location reduces the impact of the summer heat, typical of Phoenix, while the discomfort of the winter cold is reduced by its southerly location.

The five sub-indices of the TCI contribute differently to the TCI score at each location and in different seasons. Figures 6 and 7 illustrate how the contributions of the sub-indices change from season to season at Winnipeg and New Orleans and the disparate climatic strengths of the two cities. In Winnipeg, the cold winter temperatures produce negative TCI values. Low precipitation and abundant sunshine are climatic assets year-round, although the latter is diminished in winter by

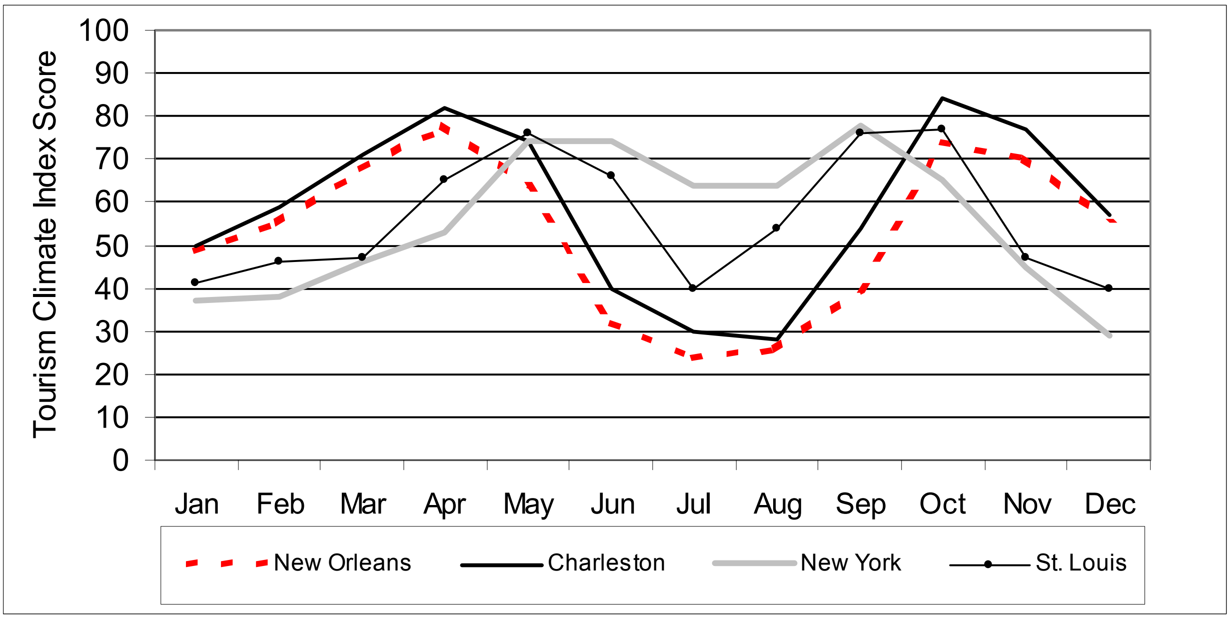

Fig. 4 Cities with bimodal-shoulder peak TCI distribution

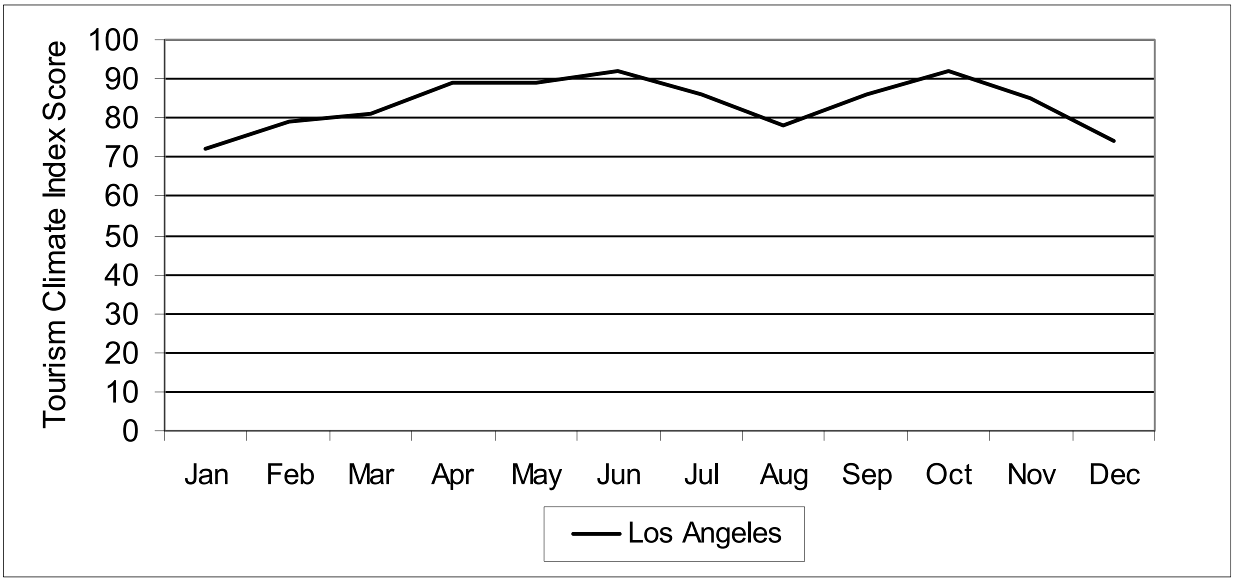

Fig. 5 Cities with optimal year-round TCI distribution

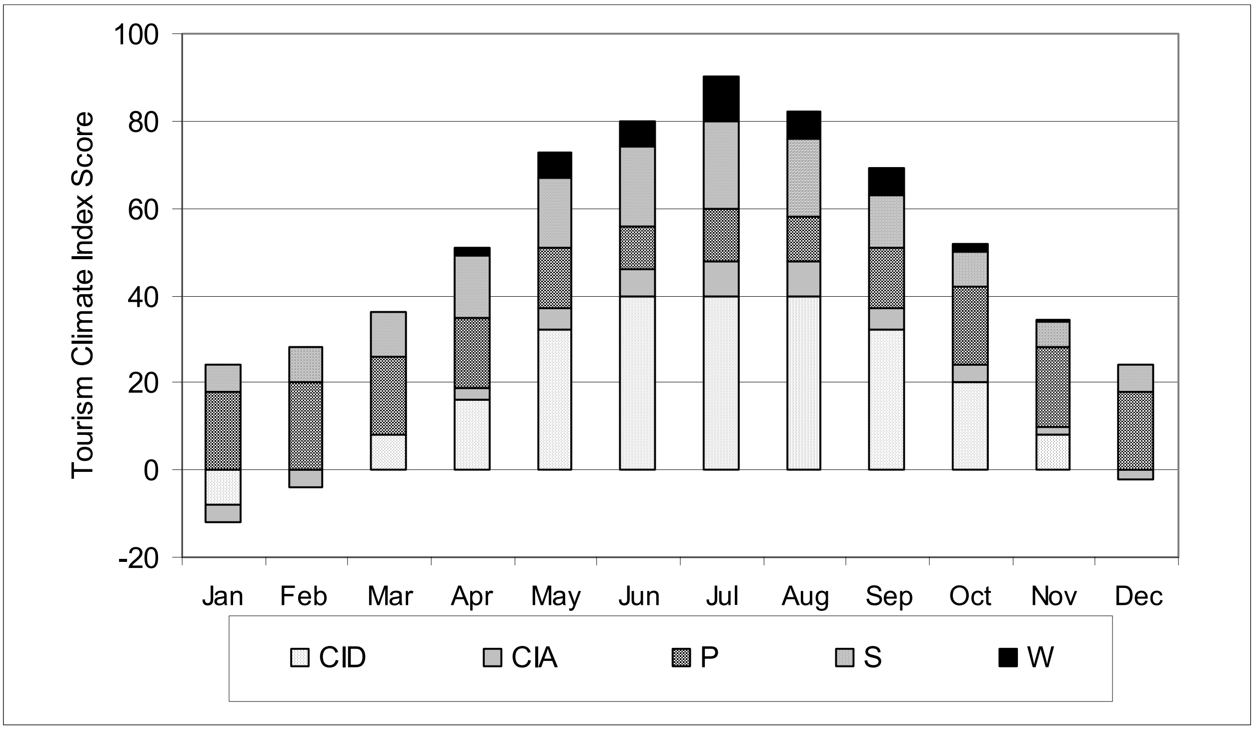

Fig. 6 Seasonal TCI sub-index ratings in Winnipeg (see Table 1 for description of sub-indices)

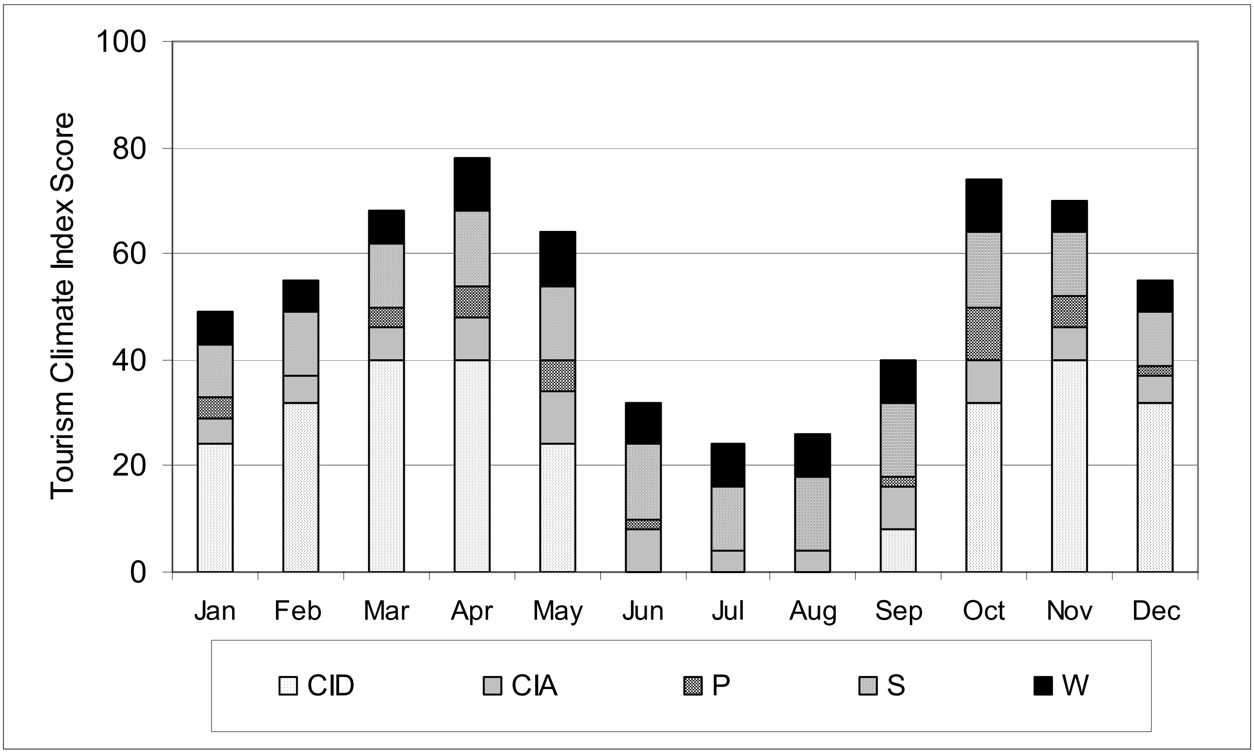

Fig. 7 Seasonal TCI sub-index ratings in New Orleans (see Table 1 for description of sub-indices)

shorter daylight hours. While the cooling effect of wind is an asset during the warm summer months and contributes to TCI score, it is detrimental to Winnipeg's TCI score in the winter when it causes high wind chills values and thus is absent from the TCI score.

New Orleans has a bimodal TCI distribution. Here the thermal sub-indices contribute maximum values in March, April and November and very little during the summer months because of the high heat index. Precipitation follows a similar pattern, with higher precipitation contributing to lower TCI scores in the summer months. Unlike Winnipeg, wind is a climatic asset in New Orleans year-round. Similarly, sunshine has a relatively stable positive contribution to the TCI throughout the year.

Validation of the Tourism Climate Index in the Tourism Marketplace

If the climate resource is a determinant of tourism demand at a location, then theoretically measures of tourism demand should follow similar seasonal patterns as the TCI scores described previously. A range of tourism demand indicators were considered to explore this question, including: number of flight arrivals, number of visitors, visitor expenditures, hotel/resort occupancy rates and hotel/resort accommodation costs. A lengthy data research revealed that none of these variables is readily available at the temporal and spatial resolution required (monthly data for individual cities), except for hotel/resort accommodation rates.

Overall, the accommodation cost curves, regardless of the price per night, resembled the TCI curves for each of the cities examined (Figures 8 to 10). Minor variations occur. For example, the increase in winter accommodation costs (Jan-March) at Muskoka resorts (Figure 8), near Toronto, can be attributed to increased demand during the alpine skiing season. The 'low season' troughs in the accommodation cost curves near Miami (Figure 9) are offset slightly from the TCI curve, extending up to two months longer in the fall season when TCI curves have already begun to rise. The slight rise in summer accommodation rates at most of the Los Angeles hotel/resorts (Figure 10), despite a concurrent drop in TCI scores, can be attributed to increased demand during the school holiday period in July and August.

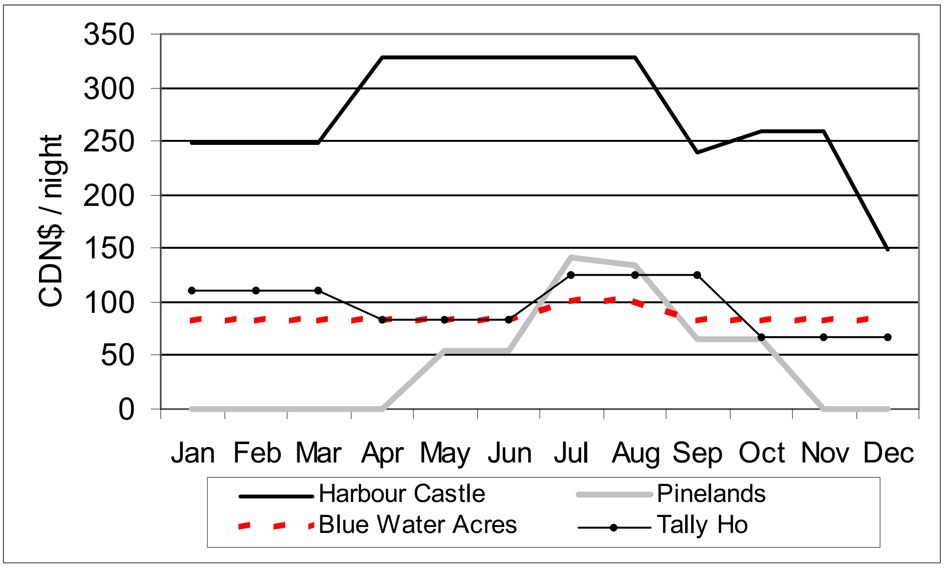

Fig. 8 Seasonal hotel/resort accommodation costs near Toronto-Muskoka (see Figure 2 for the seasonal TCI ratings of this area)

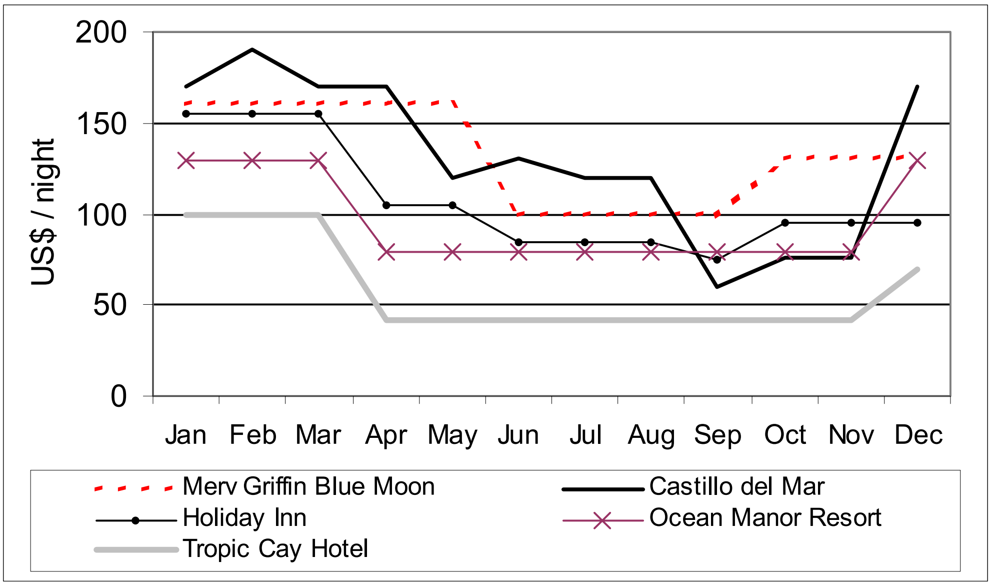

Fig. 9 Seasonal hotel/resort accommodation costs near Miami-Fort Lauderdale (see Figure 3 for the seasonal TCI ratings of this area)

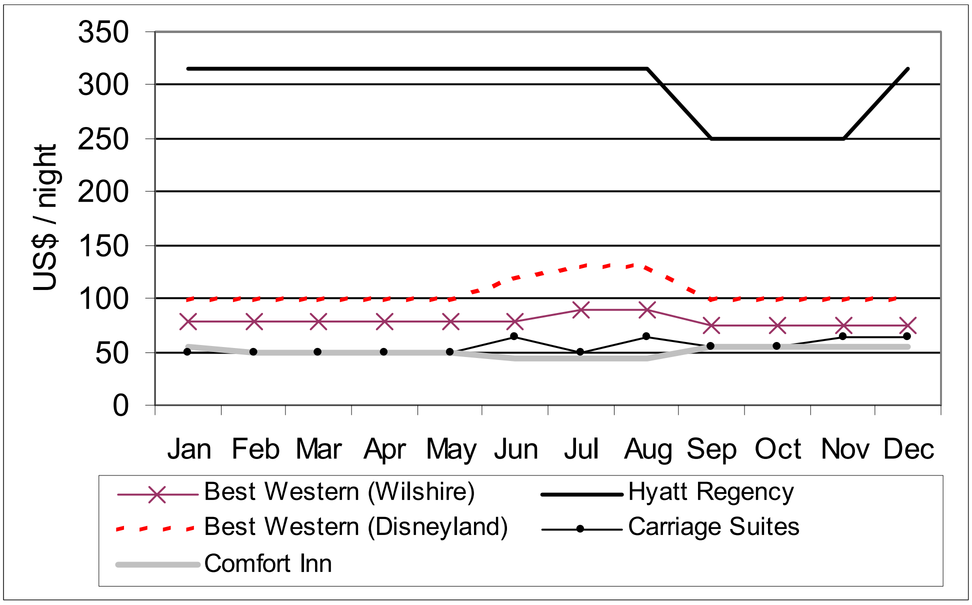

Fig. 10 Seasonal hotel/resort accommodation costs in Los Angeles (see Figure 5 for the seasonal TCI ratings of this area)

Two important caveats must accompany this analysis. First, data limitations meant the TCI could only be validated against one indicator of tourism demand. Second, the sample size of hotel/resorts at each location was small and cannot be assumed to be representative of the entire accommodation sector at any of the selected cities. Nonetheless, the results appear to suggest that the TCI provides a useful measure of the relationship between climate and tourism.

Tourism Climate Index and Climate Change

One important dimension of the tourism sector that will be sensitive to climate change is the length and quality of tourism season. Here the TCI is used to explore how the tourism climate resource is expected to change seasonally and how the length of the tourism season might be affected. Any such changes would have considerable implications for the long-term viability of tourism enterprises and competitive relationships between destinations.

Analysis of the impact of climate change on the TCI of the eight Canadian cities indicated the annual tourism climate resource improved at each location in both the 2050s and 2080s. Under both the climate change scenarios, Vancouver was the largest benefactor in the 2050s with an average monthly improvement of between 4.4 (HadCM2) and 5.3 (CGCM2) points on the TCI scale. Yellowknife experienced the largest improvement in the 2080s, with an average monthly increase of 6.3 (HadCM2) to 8.4 (CGCM2). Montreal and Toronto had the least net improvement.

Seasonally, the impact of climate change on the tourism climate resource of the eight cites was much more varied. Calgary was the only city where the TCI went up in every month under all of the climate change scenarios. Particularly strong improvements occurred in the spring, with the TCI in May increasing 7 (HadCM2) to 14 (CGCM2) points in the 2050s. The number of months with an 'excellent' rating (TCI >80) increased from two to four in both Calgary and Edmonton to the north. For comparative purposes, the TCI curve for Calgary under the CGCM2 scenarios is presented with the current TCI curve for Denver (~1500km to the south) (Figure 11). While the TCI in Calgary remains below that of Denver in the fall and winter, it becomes equal to or better than Denver in the spring and summer.

Vancouver retains the summer peak distribution and improved in all months except August and October under the HadCM2 scenario, where increased precipitation negates improved thermal comfort. The number of months in the 'excellent' category (TCI >80) increased from two to three in both 2050s scenarios and up to four in the CGCM2 2080s scenario. By the 2080s, Vancouver's tourism climate resource improves beyond that which Seattle enjoys currently.

In contrast to the improvements in the tourism climate resource in western Canada, the number of months with an 'excellent' rating in Toronto and Montreal declines from two to one and the month with the maximum TCI score shifts from June and July respectively to May under the CGCM2 2080s scenario. Both cities also experience notable declines (-6 to –16 points) in TCI ratings during the important summer holiday period (July and August). As Figure 12 illustrates, the negative impact of climate change on the summer tourism climate in Toronto, alters the TCI distribution from a summer peak to a bimodal-shoulder peak, very similar to that of New York currently. The decline in the summer TCI scores in Toronto is related to changes in thermal comfort. Specifically, under the CGCM2 climate change scenario, the number of days where the maximum temperature exceeds 32^0C increases from four (1961-90) to 19 in the 2050s and 32 in the 2080s. Under the same scenario, the maximum daily temperature extreme in August increases from 35^0C (1961-90) to approximately 46^0C in the 2050s.

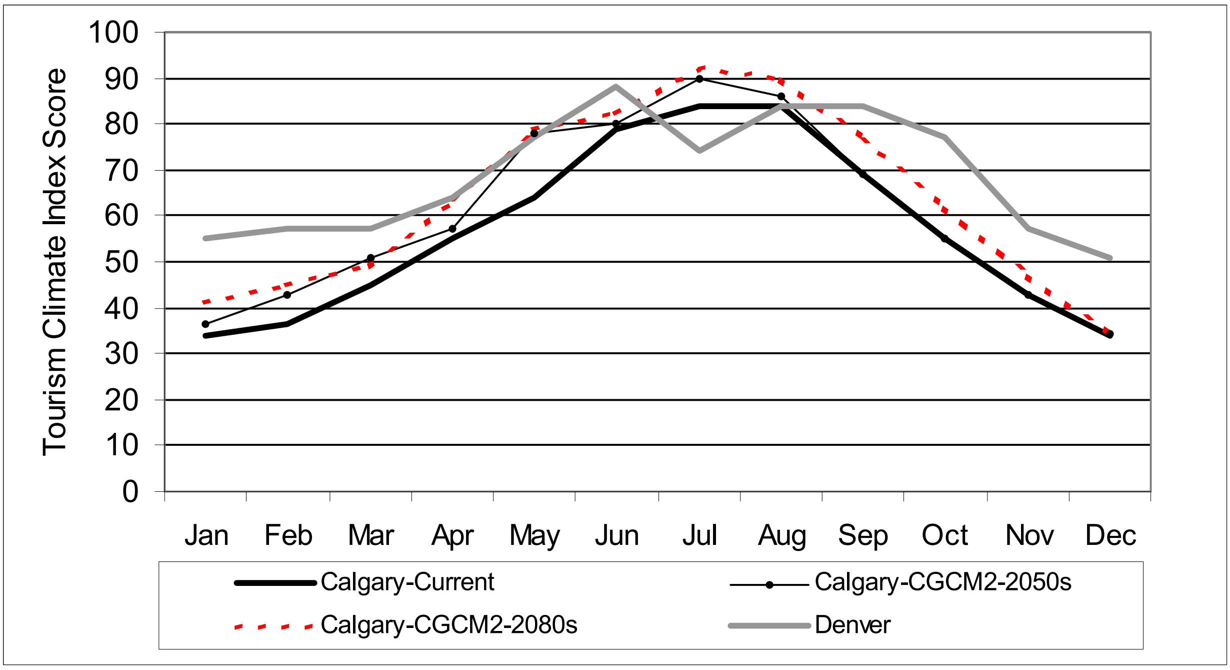

Fig. 11 Calgary TCI under CGCM2 climate change scenarios

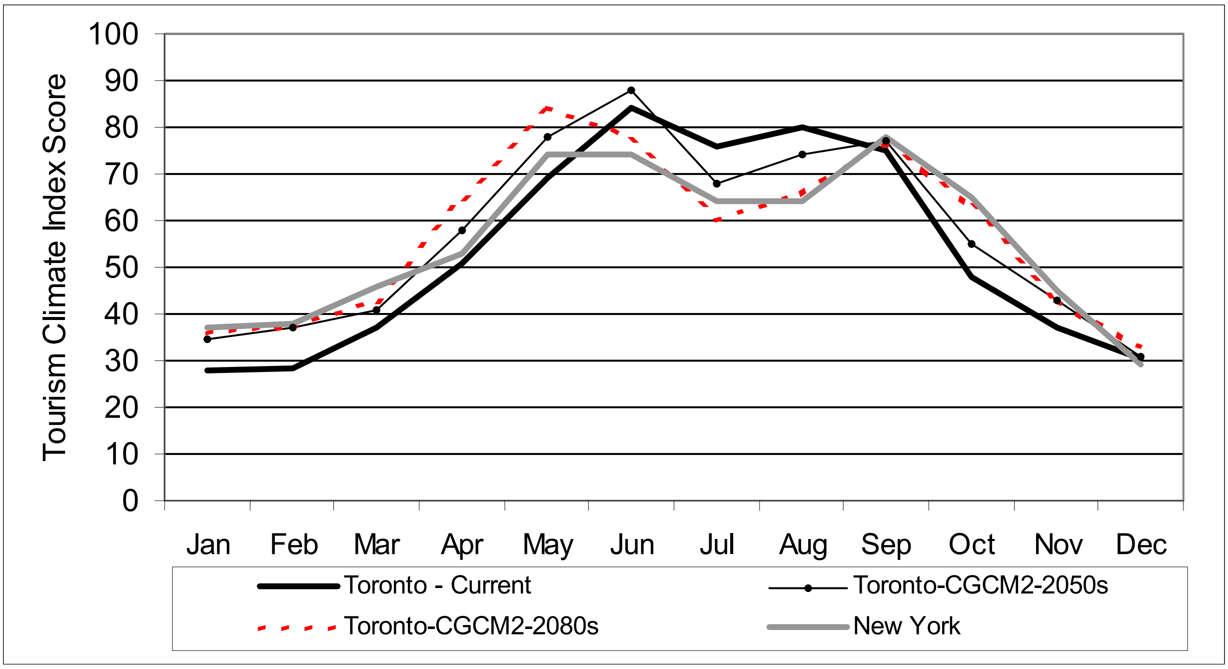

Fig. 12 Toronto TCI under CGCM2 climate change scenarios

Discussion

The findings of this study have implications for both domestic tourism in Canada and the nation's international tourism trade balance. Tourism in Canada is highly concentrated in warm-weather seasons. The third quarter (summer), when TCI scores in all of the Canadian cities examined are in the 'excellent' rating, accounts for 38% of annual domestic and 62% of the international tourism expenditures in Canada. There is also evidence to suggest that warmer summer temperatures contribute to increased tourism expenditures in Canada. Wilton and Wirjanto (1998) have estimated that 1^0C above normal summer temperatures increases domestic tourism expenditures by 4%. Consequently, increased peak TCI scores and additional months in the 'excellent' category for several Canadian cities would be expected to have a positive impact on the domestic tourism economy.

Canada's international tourism trade deficit was estimated to be CDN$2.1 billion in 2000 (Canadian Tourism Commission, 2001). The TCI analysis suggests that from a climatological perspective, Canada's tourism trade deficit could diminish under climate change. First, changes in TCI scores indicate that the tourism climate resource in Canada will improve, thus enhancing the competitive position of most Canadian regions in the international tourism marketplace (an increased tourism 'pull' factor). In particular, locations in western Canada were found to experience strong improvements in the tourism climate resource in the spring and summer. Additional research into the impacts of climate change for the tourism climate resource in the US is required to better understand how the competitive position of Canadian destinations may change. Second, Canadians spent CDN$4.9 billion traveling to warm-weather destinations (Arizona, Australia, California, Cuba, Dominican Republic, Florida, Hawaii, Mexico and Texas) in 1997. Approximately one million Canadian 'snowbirds' seasonally migrate to the US sunbelt for the winter months. Shorter and less severe winters may reduce the impetus for Canadians to travel to warm-weather destinations as a winter escape (a decreased tourism 'push' factor).

Although improvements in the tourism climate resource in Canada under climate change, as estimated by changes in the TCI, suggest a net positive impact on Canada's international tourism trade balance, this optimism must be tempered by the range of potential negative impacts climate change could have on Canadian tourism resources. Nature-based tourism is a major component of Canada's tourism industry (CDN$11.7 billion in 1996 – Environment Canada 1999). A growing body of evidence (Wall 1998, Scott and Suffling 2000, Scott et al. 2002) suggests that important elements of the environmental resource base that supports nature-based tourism in Canada is vulnerable to climate change. The critical uncertainties regarding climate change impacts on the full range of tourism resources in Canada preclude a definitive statement regarding the net impact of climate change on this economic sector.

In conclusion, the TCI is a useful index not only because it combines climatic variables based on biometeorological studies into a single index that is readily interpretable by the traveling public, but also because it is designed to measure suitability of the climate resource for the most popular tourism activities in cities – sightseeing and shopping (Jansen-Verbeke, 2001). An additional strength of the TCI is its widespread applicability, as the climatological data required for the TCI are generally available for most locations. Furthermore, TCI curves appear to reflect tourism demand, at least as measure by one tourism indicator for a sample of North American cities.

There are, however, aspects of the TCI that require further refinement and analysis. The monthly period used in the TCI needs to be replaced by a timeframe that better resembles the length of most people's vacation period (7 to 10 days). In addition to climate means, the TCI would be strengthened if additional measures of climate variability were incorporated. The thermal comfort sub-index could be upgraded to make use of more sophisticated thermal indexes, such as the Physiological Equivalent Temperature (PET) (Höppe 1999). Testing the TCI with travelers is another important area of future inquiry. This would include determining whether travelers want an 'objective' measure of the quality of the climate at tourism destinations, how easily they interpret the TCI, if the TCI provides a sufficient measure of the climate for the average traveler, and perhaps evaluating the appropriateness of the sub-index rating systems and weightings in the TCI against stated traveler preferences. Additional validation of the TCI against other tourism indicators is also needed in order to further assess the value of the TCI as a tool for tourism climatology research.

Building on the initial work of Mieczkowski (1985), this is the first empirical study of how the tourism climate resource could be impacted by projected global climate change in the coming century. The findings and methods used are a positive step in addressing Wall's (1998: 614) concern that "Although the implications for tourism are likely to be profound, very few researcher have begun to formulate relevant questions, let alone develop methodologies which will further understanding of the nature and magnitude of the challenges that lie ahead."

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