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Implications of Climate Change for Tourism in Australia

Abstract

This study assesses the impacts of projected climate change on Australia's tourism industry. Based on application of the Tourism Climatic Index, it investigates potential changes in climatic attractiveness for Australia's major destinations, and discusses implications for tourist flows and tourism planning, development and management. Australia may see considerable changes in spatial and temporal patterns of climatic suitability for tourism, with a southward shift in the most desirable conditions and a decline in the climatic attractiveness of northern locations. For destinations in which conditions are projected to decline, increased investment in indoor amenities may become increasingly necessary; where conditions are projected to improve, the provision of adequate infrastructure to accommodate potential increases in visitation and implementation of mechanisms to minimise the impacts of excess use may be more important. Adoption of a pro-active rather than reactive stance to climate change will maximise the ability of tourism stakeholders to successfully adapt.

Key Words

Climate change, impacts, Tourism Climatic Index (TCI), seasonality, Australia

1. Introduction

Tourism is one of the world's largest and fastest-growing industries. According to the United Nations World Tourism Organisation (UNWTO), a total of US$1,075 billion (€837 billion) in international tourism receipts were generated by 1,035 million international tourism arrivals in 2012, the highest numbers ever recorded (UNWTO, 2013). In 2012, travel and tourism accounted for 9% of global gross domestic product (GDP), 1 in 11 jobs, 5% of global investment and 5% of world exports (World Tourism and Travel Council (WTTC), 2013). The industry's direct contribution to global GDP is projected to grow by an average of 4.4% per annum over the next ten years, and to outpace growth in the wider economy and other industries such as retail and public services (WTTC, 2013). International arrivals are expected to reach nearly 1.8 billion by the year 2030 (UNWTO, 2012).

Similarly, climate change is an issue of major and growing global significance. According to the Intergovernmental Panel on Climate Change (IPCC, 2007), the global average surface temperature increased 0.74 ± 0.18°C in the period 1906-2005, with the linear warming trend for the past 50 years nearly twice that for the entire century. Further, each of the last 12 years (2001–2012) features as one of the 14 warmest on record (NOAA, 2012). Tide gauge data show that global mean sea level rose at an average rate of 1.8 mm per year between 1961 and 2003, with the total 20th-century rise estimated to be 17cm. While estimates vary depending upon the modeling procedures employed, climate change scenarios suggest that the global average surface temperature in 2090-2099 will increase by between 1.1 and 6.4°C relative to 1980-1999, with a "best estimate" of between 1.8 and 4.0°C. Projections regarding global mean sea level indicate a rise of between 0.18 and 0.59 meters over the same period. An increase in the intensity of extreme weather events such as tropical cyclones, and in the frequency of heat waves and heavy precipitation events, is also anticipated (IPCC, 2007).

1.1. Climate and Climate Change in Australia

Australia has been identified as one of the developed countries most vulnerable to climate change in the world (Pittock, 2009). Annual average daily maximum and mean temperatures have increased by 0.75°C and 0.9°C, respectively, since 1910 (CSIRO/ Australian Bureau of Meteorology, 2012). According to the IPCC's most recent assessment report (Hennessey et al., 2007), since 1950 there has been 0.4 to 0.7°C of warming and a rise in sea level of about 70mm across Australia. These changes have been accompanied by more heat waves, fewer frosts, more rain in north-west Australia, less rain in southern and eastern Australia, and an increase in the intensity of Australian droughts, factors already resulting in substantial stresses on water supply and impacting agriculture, industry and municipal use.

By 2020, areas within 800km of the coast are likely to experience increases in temperature of 0.1 to 1.3°C relative to 1990, with increases of 0.3 to 3.4°C by 2050, and 0.4 to 6.7°C by 2080. In temperate areas, this translates to between 1 and 32 more days per year with temperatures over 35°C by 2020, and 3-84 more such days by 2050, with 1-16 fewer days below 0°C by 2020 and 2-32 fewer by 2050 (Suppiah et al., 2007, in Hennessey et al., 2007). Decreased annual rainfall is likely over most of southern and sub-tropical Australia, though increases are likely for Tasmania, central Northern Territory and northern New South Wales.

In addition to these projected changes in temperature and precipitation over the coming century, Australia's vulnerability to the impacts of climate change is likely to be exacerbated by the increasing frequency and intensity of a range of extreme weather events, including heat waves, fires, floods, landslides, droughts and storm surges. Large areas of mainland Australia are likely to experience a reduction in soil moisture, furthering demands on water supply. The most threatened regions, according to the IPCC and other authors (e.g., Hennessey et al., 2007; Steffen, 2009), include the Great Barrier Reef, eastern Queensland, the South-West, the Murray-Darling Basin, the Australian Alps, and the Kakadu wetlands. A new suite of climate projections for Australia is due to be released by the Regional Natural Resource Management Planning for Climate Change Fund in 2014 (Australian Climate Change Science Program, no date).

1.2. Tourism in Australia

The contribution of tourism to Australia's economy is significant and increasing. In 2010-2011, the tourism industry employed nearly 514,000 people, 4.5% of the workforce. In the same year, domestic and inbound tourism together accounted for 2.5% of total GDP (valued at over AUS$35 billion) while spending by international visitors represented 8% of total exports (Tourism Research Australia, 2012b). With international arrivals predicted to increase at an average of 3.3% per year between 2010–11 and 2020–21, the inbound portion of the industry appears set to maintain its importance to the national economy. Similarly, the number of domestic trips is projected to grow slowly but steadily, at an average annual rate of 0.5% between 2010–11 and 2020–21 (Tourism Research Australia, 2012c).

Tourism activity to and within Australia varies through both space and time. Spatially, international visitors tend to concentrate in relatively few destinations, most notably Sydney and Melbourne (Table 1). Brisbane, the Gold Coast, Perth and Tropical North Queensland are the other most visited regions (Tourism Research Australia, 2012a). Sydney, Melbourne, Brisbane and the Gold Coast also top the list of the most visited destinations by domestic leisure travellers. In addition to these most popular destinations, Table 1 also lists the top ten sources of international tourists to Australia in 2011 as well as the ten most popular activities engaged in. Knowledge of inbound markets is relevant to this discussion since the travel patterns of both domestic and international travellers are influenced by climate conditions in their regions of origin as much as at their destination. Thus, changing conditions in either location might impact the size, timing, duration and/or directions of future tourism flows. Review of the most popular activities engaged in by tourists, the majority of which are outdoor-based, also emphasises the dependence of much of Australia's tourism industry on a pleasant and attractive climate.

Insert Table 1 about here

The most popular season for international tourism arrivals is the Australian summer (December-February), followed by spring (September-November), winter (June-August) and autumn (March-May). The proportion of arrivals in each of these seasons averaged across the years 1999-2006 equalled 28 percent, 25 percent, 24 percent and 23 percent, respectively. The single most popular month for international arrivals is December (11% of all arrivals) and the least popular May (6%) (Tourism Research Australia, 2007). Though these figures suggest that Australia does not suffer from the same levels of seasonality that affect other destinations, closer analysis of seasonality trends by region of origin does indicate distinct differences between the major inbound markets. For example, visitation from Japan spikes in March and August, and from Singapore in June and December. Visits from New Zealand are highest from April to October, whereas the majority of UK visitors arrive in the northern hemispheric winter, October through March (Tourism Research Australia, 2007). Seasonality has implications for the availability and pricing of tourism products (flights, accommodations, etc.), as well as for the short-term management of tourism businesses (budget management and cash flow, staffing and employment, etc.). Thus, projected climate change in Australia and her major inbound tourism markets may have substantial impacts on the temporal and spatial nature of the Australian tourism industry.

2. Research on Climate Change and Tourism in Australia

A large body of work exists on the potential impacts of climate change on the Australian environment, much of which has potential relevance for outdoor recreation and tourism activity. Winn et al. (2006), for example, have documented saltwater intrusion into freshwater swamps in the Northern Territory, which could impact the distributions of species popular among outdoor enthusiasts, whether for hunting and fishing, or viewing and photography. Several studies (Smithers et al., 2003; Chambers, 2005; Chambers et al., 2005; Beaumont et al., 2006) have noted the earlier arrival of migratory birds as well as range shifts and expansions for several species, with similar implications for birding activity. Hoegh-Guldberg (1999), Done et al. (2003), Berkelmans et al. (2004), Jones (2004) and De'ath et al. (2009) have analyzed bleaching events on the Great Barrier Reef, one of Australia's premier tourism attractions. Based on a survey of users at that site, Kragt et al. (2009) conclude that "a hypothetical reduction in fish abundance, coral cover and coral diversity of 80, 30 and 70 per cent, respectively, may lead to an 80 per cent decrease in the number of reef trips taken by divers and snorkelers. (p. 215)" Shifts in species composition, and in the quantity and quality of flora and fauna, could significantly impact the attractiveness of both terrestrial and marine national parks and other protected areas throughout Australia.

Despite the obvious dependency of outdoor recreation/tourism activities on climatic conditions, as well as the mounting evidence regarding the physical characteristics of climate change and its likely socioeconomic implications, research on the likely impacts of climate change on tourism in Australia remains limited. Indeed, a comprehensive review of the literature revealed only twelve research papers pertaining to climate change and tourism in Australia. The majority of these address winter sports and, thus, are specific to a small subset of total Australian tourism activity (Galloway, 1988; König, 1998; Bicknell and McManus, 2006; Hennessy et al., 2008; Pickering et al., 2010; Pickering and Buckley, 2010; Pickering, 2011). In contrast, the current paper considers a wide range of light to moderate physical activities as well as the role of indoor amenities, thus having implications for a much broader range of year-round domestic and international tourism activity.

A handful of studies have analysed stakeholder perceptions of climate change and the need and available options for adaptation. Turton et al. (2010) studied the impacts of climate change and the options for and barriers to adaptation as perceived by tourism stakeholders in four moderately to highly vulnerable Australian destinations. They concluded that, while most stakeholders take climate change seriously, perceived uncertainties discourage investment in climate change adaptation. Similarly, Roman et al. (2010) found that while the majority of tourism stakeholders at Alpine Shire in Victoria considered climate change to be an important issue, they also perceived it to be "beyond their capacity to accommodate." Pham et al. (2012) found that regions that rely heavily on domestic tourism are likely to face important economic flow-on effects of climate change-induced tourism impacts.

Studies of the current and/or future spatial and temporal distribution of climate resources for summertime tourism in Australia are extremely rare. Only one peer reviewed article of this kind was identified, Hadwen et al.'s (2011) analysis of whether climatic (minimum and maximum temperature, and precipitation) or institutional factors (the timing of school holidays) drive Australian seasonality. In five out of six climate zones, the explanatory power of the climate variables was found to be much higher than that of the institutional factor, suggesting that climate change is likely to have major impacts on the spatial distribution, timing and viability of nature-based tourism in Australia. No other projections of future climate conditions with respect to tourism in Australia appear to exist. The Australian Government's "Climate Change Guide" for Australian tour operators devotes a single sentence to the description of future conditions: "The attractiveness of certain tourism destinations may change depending on the extent and nature of climate change in that area" (Australian Government Department of Resources, Energy and Tourism, 2009, p. 4).

In light of this deficiency, the purpose of the study presented here is to assess the impacts of projected climate change for Australia's tourism industry. More specifically, using the Tourism Climatic Index introduced below, the study investigates potential changes in climatic attractiveness for Australia's major tourism destinations over the coming century, and discusses the likely implications of these changes for flows of tourists as well as for tourism planning, development and management.

3. Method

3.1. The Tourism Climatic Index

The Tourism Climatic Index (TCI) was developed by Mieczkowski (1985) as the first ever evaluation of the suitability of the world's climates for the purpose of general tourism activity. Thus, the TCI was designed to encompass the most commonly engaged in tourist pastimes such as sightseeing, shopping, and other outdoor activities involving low to moderate levels of physical exertion. The index is based on monthly means for seven climatic variables, namely: (i) maximum daily temperature; (ii) mean daily temperature; (iii) minimum daily relative humidity; (iv) daily relative humidity; (v) precipitation; (vi) daily duration of sunshine; and, (vii) wind speed. Five other variables deemed theoretically relevant to tourism comfort and well-being were excluded due to a lack of sufficient data with which to construct the index. Of the seven remaining variables, Mieczkowski related the first four to thermal comfort, with (i) and (iii) forming a daytime comfort index (representing conditions between noon and 4pm, when tourists tend to be most active outdoors) and (ii) and (iv) a daily comfort index (representing conditions over a full 24-hour period). The seven variables were then weighted by Mieczkowski, according to their relative influence on tourist well-being, to form the final index:

$$TCI = 8CID + 2CIA + 4R + 4S + 2W,$$

Where: CID = daytime comfort index (composed of maximum daily temperature and minimum daily relative humidity); CIA = daily comfort index (composed of mean daily temperature and daily relative humidity); R = precipitation; S = daily sunshine; and, W = wind speed. Each variable takes on an optimal rating of 5.0, and Mieczkowski suggested the classification scheme outlined in Table 2 be used to distinguish the suitability of a location's climate for tourism based on its overall TCI score. Further details regarding the construction of the index can be found in the original paper (Mieczkowski, 1985). The TCI has been successfully incorporated as a measure of climatic attractiveness in combination with projections of climate change in the Mediterranean (Amelung & Viner, 2006), northwest Europe (Nicholls & Amelung, 2008) and at the global level (Amelung, Nicholls & Viner, 2007).

Insert Table 2 about here

3.2. Data

The analysis required the use of two major datasets, the CRU CL 1.0 dataset, which contains mean monthly climatology data for the period 1961 to 1990 and was assembled by the Climatic Research Unit at the University of East Anglia, Norwich, UK (New et al., 1999) and results from the integration of the Hadley Centre's HadCM3 Global Circulation Model (GCM) forced with a range of greenhouse gas emissions scenarios as per Johns et al. (2003). Details of the creation of these datasets beyond those referenced in the two paragraphs to follow can be obtained in the original manuscripts.

The CRU CL 1.0 data (New et al., 1999) are in the form of a grid-based set representing mean monthly surface climate over all land areas around the globe (excluding Antarctica) for the period 1961-90. The set includes interpolations from station data (numbering between 3,615 for wind speed and 19,800 for precipitation) to a 0.5º latitude by 0.5º longitude grid for the following variables: precipitation and wet-day frequency; mean temperature and diurnal temperature range (from which maximum temperature and minimum temperature can be determined); vapour pressure; sunshine; cloud cover; ground-frost frequency; and, wind speed. This data set is widely recognised as the best available. Values for all the component variables of the Mieczkowski index can be extracted from the CRU CL 1.0 dataset, either directly or with some straightforward manipulation. This dataset formed the basis for the construction of the historical TCI values, i.e., for the period 1961-90 (referred to from hereon as the 1970s).

The integration of the Hadley Centre's HadCM3 Global Circulation Model (GCM) forced with a range of greenhouse gas emissions scenarios (Johns et al., 2003) was used to project future climatic states for three time periods: 2010-2039 (the 2020s); 2040-2069 (the 2050s); and, 2070-2099 (the 2080s). The spatial resolution of these gridded data is 2.5º latitude by 3.75º longitude. Of the forty individual scenarios within the four scenario families identified in the IPCC’s Special Report on Emissions Scenarios (IPCC 2000), namely, the A1, A2, B1, and B2 scenario families, only two specific scenarios, A1F and B1A, were considered here. The A1F scenario is at the high-end of the spectrum of climate change projections, assuming a fossil fuel-intensive world characterised by rapid economic growth, whereas the B1A scenario is less extreme, envisaging far greater emphasis on sustainability solutions accompanied by more equitable and resource-efficient economic growth (IPCC, 2000). Together the A1F and B1A scenarios demarcate the range of plausible speeds and magnitudes of climate change.

4. Results

To maximise the range of findings and the resulting discussion of their potential implications, three sets of analyses were conducted. First, TCI scores for the four time periods (1970s, 2020s, 2050s and 2080s) and two climate change scenarios (B1A and A1F) under consideration were calculated and mapped for the primary tourism season in Australia, the months December, January and February (DJF). Second, the numbers of months per annum exhibiting ‘very good’ or better (TCI ≥ 70) climatic conditions for tourism activity were calculated and mapped for each time period and scenario. Third, charts illustrating TCI scores for the four time periods and two scenarios were constructed for five popular destination cities throughout the country – Brisbane, Cairns, Melbourne, Perth, and Sydney. Since the two sets of maps referenced do not show well in black and white, readers of the hard-copy version of this journal are directed to the online version where he or she may view the entire set of maps in full colour.

4.1. TCI Scores for December-February, 1970s-2080s

Maps illustrating results of the TCI analysis averaged over the months December-February – the Australian summer – for the four time periods and two climate change scenarios considered are presented and discussed. After a review of historical conditions, projected changes in climatic attractiveness are analysed, first for the more conservative B1A scenario, and then for the more extreme A1F case.

4.1.1. The 1970s. Historically, Australia has demonstrated a distinct latitudinal gradation in climatic attractiveness during the summer season, with the best conditions occurring in the south and a decline to ‘acceptable’ and then ‘unfavourable’ conditions with northward travel. The very best (‘ideal’ and ‘excellent,’ TCI ≥ 80) conditions occur along the south coast, including the popular tourism destinations of Perth and Adelaide, while ‘very good’ and ‘good’ (TCI ≥ 60) conditions prevail throughout the remainder of the southern third of the nation, including Melbourne, Canberra and Sydney. To the north, however, including the northern third of Western Australia and the northern half of the Northern Territory, climatic conditions are classified as ‘unfavourable’ (TCI < 40) (Figure 1).

Insert Figure 1 about here

4.1.2 2020s-2080s, B1A. Over the course of the coming century, and assuming the more resource-efficient growth trajectory characteristic of the B1A scenario, the TCI analyses portray a gradual poleward shift in the broad bands of climatic attractiveness previously identified for the 1970s. The expansion of the area classified as ‘unfavourable’ in terms of its climatic attractiveness for general tourism activity is particularly noticeable, extending over the majority of the northern half of the nation by the 2080s, as is the reduction in extent of the region previously classified as ‘ideal-excellent’ in the southwest and its gradual replacement by a ‘good-very good’ climate. Conditions in the southeast tip of the nation appear set to improve, however, with a long stretch of coastline seeing a shift from ‘good-very good’ to ‘excellent-ideal’ climatic conditions, including Melbourne and Sydney as well as Canberra inland. Conditions in Brisbane and along the Gold Coast appear to remain ‘acceptable’ (Figures 2-4).

Insert Figures 2-4 about here

4.1.3. 2020s-2080s, A1F. The fossil fuel-intensive A1F scenario suggests a similar shift in climatic attractiveness to that indicated using the B1A assumptions, though in this case the shift occurs far more rapidly and over a more extensive area (Figures 5-7). By the 2080s the entire northern half of Australia is projected to fall within the zone of ‘unfavourable’ climatic conditions for general tourism activity during the months December-February, encompassing the entirety of Queensland and stretching as far south as key tourism destinations including Brisbane. The zone of ‘good-very good’ climatic attractiveness is considerably reduced, though the entire southern coast does continue to enjoy these conditions, with portions of the southeast tip still classified as ‘excellent-ideal.’

Insert Figures 5-7 about here

4.2. Numbers of Good Months, 1970s-2080s

Maps illustrating the number of months exhibiting a TCI of 70 or higher (referred to as ‘good months’) for the four time periods and two climate change scenarios considered are presented and discussed. After a review of historical conditions, projected changes in the number of good months per annum are analysed, first for the more conservative B1A scenario, and then for the more extreme A1F case.

4.2.1. The 1970s. Australia currently exhibits wide variation in the number of good months (TCI > 70) enjoyed in terms of climatic attractiveness (Figure 8). The least attractive areas, with three or fewer good months, include the most northerly portions of Western Australia, the Northern Territory, and Queensland, including Darwin and Kakadu National Park, as well as certain areas along the southeast coast of Victoria. The majority of the nation enjoys between five and eight good months. The most climatically attractive area (for nine-ten months of the year) is the Nullarbor Plain.

Insert Figure 8 about here

4.2.2. 2020s-2080s, B1A. The B1A scenario suggests that, while some areas will likely increase in climatic attractiveness as a result of climate change, others will lose out (Figures 9-11). The situation in the far north will, as a whole, remain relatively static. Though some grid cells indicate a gain of one month of climatically attractive conditions, others indicate a loss of a month. As a whole, the region will continue to experience up to only three-four months of good climatic conditions for general tourism activity. The southeast portion of the country, in contrast, appears set to gain in climatic attractiveness, with an increase in good months from four or less to four-seven by the 2080s. The longest period of good conditions will continue to occur along the south coast, from Esperance to Adelaide and inland. The spatial extent of the area enjoying nine or more good months peaks in the 2020s according to the B1A scenario, with declines of a month or two into the 2050s and 2080s. The majority of the landmass, from the central band of Western Australia through the southern half of the Northern Territory and southern Queensland, is projected to continue to experience five-seven months of good climatic conditions throughout the period analysed.

Insert Figures 9-11 about here

4.2.3. 2020s-2080s, A1F. As anticipated, the A1F scenario projects a similar pattern in alteration to the distribution of climatic attractiveness as does B1A, though at an accelerated rate (Figures 12-14). Indeed, the A1F map for the 2050s (Figure 13) is extraordinarily similar to that for the 2080s according to B1A assumptions (Figure 11). By the 2080s, the east-west zone of locations experiencing eight or more good months is shifted southward and, hence, shrunk quite noticeably. However, the southern coastline is projected to see continued increases in the number of good months, with the area bounded approximately by Ceduna, Port Lincoln and Wilpena in South Australia enjoying eleven or twelve months of climatic conditions with TCI scores in excess of 70 each year. Similarly, the coastlines of Victoria and New South Wales exhibit increases in the number of good months anticipated, from the present range of four-six to a range from five to nine.

Insert Figures 12-14 about here

4.3. TCI Scores for Selected Cities

The previous two sets of analyses facilitated somewhat coarse-level illustrations of potential changes in climatic attractiveness across the entirety of Australia. Given the size of the nation and the intense spatial concentration of tourism in a relatively small number of prime destinations, finer scale analysis was considered extremely desirable. As a result, charts illustrating TCI scores for the four time periods and two scenarios considered were constructed for five popular destination cities throughout the country – Brisbane, Cairns, Melbourne, Perth, and Sydney.

4.3.1. Brisbane. Brisbane is currently one of the top three overnight travel destinations for both domestic and international tourists in Australia (Table 1). As shown in Figure 15, historically Brisbane has enjoyed over four months (July-October) of climate conditions considered ‘very good’ or better for general tourism activities (TCI > 70). Throughout the remainder of the year conditions may be classified as ‘acceptable’ to ‘good’ (TCI score of 50-69). In future decades, and as a result of climate change, it appears that, although the duration of the peak climatic season may increase marginally, its timing is likely to shift forward, with ‘very good’ or better conditions arriving in June but dissipating by October. Conditions during this peak period also appear set to improve, with scores reaching into the 80s (‘excellent’) for at least one month. These general patterns hold under both the B1A and A1F scenarios.

For the months November-April, however, climatic conditions are projected to decline in attractiveness for tourism activity, most notably under the A1F scenario, according to which conditions in Brisbane might be classified as ‘marginal’ at best (TCI < 50) for three months by the 2050s and five months by the 2080s. Similar reductions in climatic attractiveness for the months November through April are suggested by the B1A scenario, though the magnitudes of these reductions are substantially less pronounced.

Insert Figure 15 about here

4.3.2. Cairns. The attraction of Cairns as a major tourism destination lies in its tropical climate and its proximity to the Great Barrier Reef. As Figure 16 shows, climatic conditions in Cairns have historically been ‘very good’ or better (TCI > 70) for general tourism activity for five months of the year (June-October), with ‘excellent’ conditions (TCI > 80) from July through September. Unlike Brisbane, to the south, however, Cairns has always seen a greater annual variation in TCI scores, with ‘marginal’ or worse conditions (TCI < 50) lasting from December through March. In future, conditions during June through October appear set to remain ‘very good’ or better under both the B1A and A1F scenarios, other than for the most distant, 2080s timeframe under the more dramatic A1F scenario; in that case, a steep decline in conditions is predicted in September, thereby shortening the peak climatic season to three months.

For the months November through April, reductions in TCI scores are projected for every month under both scenarios, with the greater reductions suggested by the A1F scenario. As early as the 2020s the analyses suggest that Cairns may experience TCI scores in the 30s (‘unfavourable’ for general tourism activity) for up to three months according to A1F assumptions, with scores dropping into the high teens (‘extremely unfavourable’) for the months of January and February by the 2080s. As a result, the annual range of TCI scores in Cairns is likely to increase in size, by over 20 points according to the A1F scenario for the 2080s.

Insert Figure 16 about here

4.3.3. Melbourne. Melbourne is currently the second most visited destination for overnight trips among both domestic and international tourists in Australia (Table 1), and, as shown in Figure 17, has historically enjoyed ‘very good’ or better climatic conditions for general tourism activity from November through March-April, with ‘excellent’ conditions (TCI > 80) for at least one month. In the future, Melbourne may experience an even longer period of prime climatic conditions, with TCI scores reaching 70 or better starting in October and lasting through April for all three timeframes under the B1A scenario, and lasting into May by the 2080s according to the A1F scenario.

Conditions are also set to improve in the months of May through September, which have historically experienced TCI scores in the mid-40s to mid-50s (‘marginal’ to ‘acceptable’). These improvements are most marked in May under the B1A scenario, and for May and September under A1F assumptions, contributing to the lengthening in peak season already described above. By the 2080s under the A1F scenario, Melbourne may experience only three months of less than ‘very good’ climatic conditions (June-August) and with low scores in the high 50s these conditions would still be considered acceptable for general outdoor tourism activity. Of further note under the A1F scenario is the considerable reduction in the annual range of TCI scores, from almost 40 points in the baseline period to approximately 30 points by the 2080s.

Insert Figure 17 about here

4.3.4. Perth. Perth, on Australia’s west coast, is another popular travel destination for both Australians and foreign visitors (Table 1). Historically, Perth has enjoyed a distinct peak season in terms of climatic attractiveness for tourism activity, with TCI scores in excess of 70 from October through April (Figure 18). In the future, this peak season is likely to increase in length according to the B1A scenario, beginning in September by the 2050s and lasting until April. The months of October and November appear likely to enjoy especially good conditions, with TCI scores potentially reaching into the high 80s and 90s (‘excellent’ to ‘ideal’). While the months of January through March are projected to see slight declines in their TCI scores according to the B1A scenario, their scores do remain above 70 across all three future timeframes. Conditions also appear likely to exhibit some improvement in the months that are currently less than ideal for outdoor tourism activity (May-September). These improvements are in the order of 10 points per month according to the B1A scenario, resulting in ‘acceptable’ conditions between June and August.

However, according to the A1F scenario, a distinct shift in the pattern of climatic attractiveness appears possible, from the currently well-defined modal, peak/off-peak situation, to a more bi-modal pattern by the 2080s. This shift is caused by the combination of improved conditions in October-November and declining conditions in the months December through March, and results in two peaks in climatic attractiveness, in October-November and

April, with a major new trough in February. While the months June and July might be considered the second of the troughs in this new, bi-modal structure, it should be noted they are projected to enjoy considerable improvements in conditions relative to the current day. Indeed, the range in TCI scores, which has historically been from approximately 40 to 90, appears set to decline by over 15 points (to 55-90) by the 2080s.

Insert Figure 18 about here

4.3.5. Sydney. Sydney is the most visited destination in Australia. Of the five cities considered in this analysis, Sydney also demonstrates the least annual variation in climatic attractiveness, with scores ranging between 50 and the high 70s throughout the year (Figure 19). The best conditions for tourism activity (TCI > 70) currently occur between the months of October and April. In the future, climatic attractiveness appears set to increase from April through October but decrease between December and March. By the 2080s, Sydney might enjoy the best conditions for general tourism activity between April and November, with scores dropping significantly below 70 in only December through March, according to the A1F scenario. Further, in a similar fashion to the alterations noted for Perth, Sydney may also begin to exhibit a bi-modal pattern in its tourism attractiveness, with peaks forming over time in April-May and September-October. However, while the identification of months with scores in excess of 70 might at first suggest rather pronounced shifts in peak season, it should be noted that the annual variation in TCI scores remains minimal and that the minimum TCI scores recorded remain in the mid-50s, i.e., still ‘acceptable’ for tourism and far more desirable than conditions in the off-peaks in the other destinations analysed.

Insert Figure 19 about here

5. Discussion

The analyses presented above project considerable changes in the spatial and temporal patterns of climatic suitability for general tourism purposes throughout the course of the coming century in Australia. As demonstrated, destinations in the north, notably Darwin, Kakadu National Park and much of Queensland, including key access points to the Great Barrier Reef such as Cairns and Townsville, are projected to face deteriorations in their climatic suitability throughout large periods of the year. These likely reductions in climatic attractiveness appear most pronounced during Australia's summer months (December-February), when the highest proportion of international tourists currently arrive. Similarly, Brisbane and the Gold Coast appear set to suffer substantial declines in their climatic attractiveness during the high season. In contrast, more southerly destinations including Melbourne, Sydney, Adelaide and long stretches of the South Coast are projected to enjoy substantial improvements in their already desirable climatic conditions, with the potential for much longer periods of weather suitable for general tourism activities. Though some southern locations may see declines in conditions in the December-February period relative to the current day, conditions remain in the acceptable or better category and are more than balanced out by the considerable lengthening of the climatically attractive season. Extended periods of optimal climatic conditions, particularly in combination with increases in the reliability of these optimal conditions, suggest the opportunity for increased participation in the kinds of outdoor activities in which visitors already prefer to engage and which Tourism Australia's marketing materials emphasise, including shopping, going to beaches and markets, and visiting outdoor attractions such as state, national, and wildlife parks, zoos, public gardens and historic sites (Table 1).

It should at this point be noted that the TCI was intended as a tool to aid in the identification of climatically optimal vacation destinations, and the most desirable times at which to visit certain destinations, rather than as a predictor of inbound travel. A high score on the TCI does not necessarily translate into a high level of visitation. Successful destinations must exhibit a range of qualities, including adequate transportation links and infrastructure, appropriate numbers and kinds of accommodations, events and attractions, and a safe and pleasant environment, in addition to offering an appealing climate. Similarly, a low score on the TCI does not necessarily discourage visitation, most notably in the case of destinations offering exceptionally high-quality natural and/or cultural tourism resources. The purpose of this study was to identify the spatial distribution of conditions climatically attractive for general tourism activity, rather than to predict changes in the number of visitors to Australia as a whole or to individual destinations as a result of climate change; the findings can nevertheless be used to form the basis of a series of observations with regards to the climatic suitability of particular Australian regions and cities and resulting implications for tourism planning, development and management.

Beginning in the north and northeast, it is clear that current climatic conditions – which are far from optimal for general tourism activity – do not preclude visitation, most notably due to the range and quality of natural attractions the regions have to offer. In the future, however, climatic conditions are projected to decline even further. More importantly, and factors not incorporated into the current analyses, are the alterations to the natural resource base likely to accompany this climate change. Continued deterioration of the Great Barrier Reef, for example, is likely to lessen its appeal as a destination, both for casual day trippers and dedicated scuba divers. In the short term, operators in this area might choose to revisit their own environmental practices and considerably strengthen the educational components of their programs and activities – for example, to inform participants about the direct damage they can cause to resources, e.g., by touching coral, as well as their more indirect contributions to climate change, e.g., via their energy and resource inefficiency – so as to expand the lives of their operations as much as possible. Unfortunately, however, climate change is an international phenomenon that knows no boundaries, and in the longer term, despite the best efforts in localised areas, tourism businesses in the north and northeast might need to seriously consider the nature of their offerings, perhaps directing their future investments towards indoor amenities as climatic conditions for outdoor activities continue to decline.

In the south, in contrast, conditions are already good for general tourism activity for close to or over one half of the year, and in future the length of the high season is projected to increase into the current climatic shoulder seasons. For destinations like Melbourne, which currently demonstrates a clear peak/off-peak climatic pattern, the lengthening of the season implies that tourism businesses may need to prepare to accommodate greater levels of visitation for longer periods of the year, which, for the smaller and/or family-owned and operated businesses typical of the majority of tourism enterprises, may have implications for factors such as the hiring of seasonal staff. Under the A1F scenario for the 2080s, Perth and Sydney would become year-round destinations from the perspective of climatic attractiveness, again likely requiring modifications to day-to-day and previously more seasonal operations on the part of smaller, family businesses. Improving conditions in the Australian winter period (June-August), which happens to coincide with the northern hemisphere's school summer holidays, offers the potential for increasing family and youth travel, particularly if summer conditions in the southern Mediterranean, currently the most popular summer destination in the world, decline as projected (Amelung et al., 2007).

The potential bi-modality identified for Perth and Sydney may or may not have significant implications for the provision of tourism opportunities. If the new pattern consisted of two distinct peaks interspersed by periods of dramatically deteriorated conditions, one might predict a complete shift in tourism activity, with concomitant implications for load and occupancy rates, staffing needs, and purchasing requirements. However, the data suggest that the peaks and troughs will be far less pronounced, with the two peaks of ‘excellent-ideal’ conditions preceded and followed by ‘acceptable’ or better conditions. As a result, the implications are more likely to mirror those identified in the paragraph above, i.e., essentially year-round businesses but with softer periods between the peaks of ‘excellent-ideal’ conditions.

The work by Hadwen et al. (2010) on the influence of climate conditions on current visitation to protected areas in Australia provides an opportunity to explore the impact of climate change on future visitation. In the equatorial, tropical (e.g. Cairns) and desert climate zones in Australia, observed visitation to protected areas is strongly concentrated in and around the Australian winter (June-August). Maximum and minimum temperatures and the amount of precipitation are strong determinants of visitation, and these are also key elements in the TCI. The strong reductions in TCI scores in Cairns in summer and the slight reductions in winter suggest that visitation to the region will likely remain winter-peak. According to Hadwen et al. (2010), visitation to subtropical protected areas (around Brisbane, Gold Coast) is trimodal, and is not as strongly climate-driven. Our analyses suggest that climatic conditions in this area will improve for (part of) only one of the peak seasons (September-October), and deteriorate for the other two (December-January, and April). Given the limited role of climate, this may have little impact on demand, but it may also give rise to a new visitation regime. The observed seasonality pattern of visitation to protected areas in the temperate zones (including cities such as Sydney and Melbourne) is decidedly summer-peak (DJF), and moderately influenced by minimum and maximum temperatures and by precipitation. Climate change is projected to generally increase conditions in the Australian summer in this area, at least until the 2020s. Afterwards, conditions will further improve in all seasons except December-February. At some point, an effort may therefore be required to try and shift some of the demand from the summer season to the rest of the year.

As previously suggested, climatic attractiveness is but one factor influencing the successful development of a location as a tourism destination. In the case of Australia, the purpose and current timing of visitation among different segments of the inbound market is also an issue deserving further consideration. As identified in Table 1, the three main sources of inbound tourists are New Zealand, the United Kingdom, and Japan. Arrivals from New Zealand fluctuate throughout the year, with peaks in April, July and September and the lowest level of arrivals in January and February, New Zealand's own summer period. In contrast, arrivals from the UK exhibit a distinct modal pattern, peaking between November and March and dropping off significantly between May and September, the northern hemispheric summer. The highest numbers of Japanese visitors arrive in March and August, resulting in a bi-modal pattern of arrivals (Tourism Research Australia 2007). These kinds of variations in seasonality can be accounted for by a variety of factors; not only do weather/climate in both the origin and destination play a role, but the timing of school/university holidays and special events, and the pricing of transportation and accommodations, also impact tourists' choices regarding when to travel. As a result, while increasing climatic attractiveness may make a destination more desirable at a particular time, this does not necessarily mean that inbound travellers are able to capitalise on those improved conditions, particularly due to temporal and financial restrictions on whether and when they can afford to travel. Rising transportation costs are an additional factor not captured by the TCI analysis. Australia's popularity as a tourism destination – despite its remoteness from most major tourist markets – has been greatly boosted by relatively low transport costs. Possible increases in transport costs, e.g., as a result of oil shortages or climate change policies, may impact Australia's competitive position and, hence, its desirability as a long-haul destination.

Purpose of visit is also relevant. In 2011, 44 percent of inbound international visitors cited a holiday as their main reason for their visit. Twenty-four percent came to visit friends and relatives, twelve percent for business, and six percent for educational purposes (Tourism Research Australia 2012c). A good proportion of business and educational travel is unlikely to be impacted by changing climatic attractiveness, other than that to large conventions for which the choice of location may well reflect the quality of the environment and variety of available amenities. Holidaymakers, in contrast, are likely to place far greater importance on the climatic conditions in a destination. Those visiting friends and relatives are unlikely to choose not to visit, but may alter the timing of those visits so as to coincide with the most desirable conditions at their destination should their schedules allow.

Moving from the level of the tourist and the tourism provider to the facilitators of tourism activity, namely local, regional and national government, the potential for considerably increased inbound tourism presents both opportunities and potential costs. From an economic perspective, increased inbound traffic is likely to be perceived as a boon, for individual businesses as well as for all tax receiving entities. However, rising arrivals may also require additional tourism infra- and superstructure to be constructed, with implications for the planning, location, development, funding and management of new accommodations, transportation hubs and routes, and attractions. Furthermore, increases in tourism activity may also result in the placing of additional – and potentially excessive – demands on tourism resources by consumers. For example, warming conditions will certainly create rising demand for air conditioning, further contributing to climate change due to the energy use associated with its operation. With growing levels of visitation, destinations must also anticipate and plan effectively to avoid over-development, through the development and implementation of the mechanisms necessary to control the use of or access to their most fragile resources.

At all levels, from tourism businesses to local, regional and national government, the ability to successfully adapt to new climatic conditions – regardless of whether those conditions offer opportunities or pose potential threats – will depend heavily upon their recognition of and reaction to climate change as an issue, i.e., the adoption of a pro-active rather than reactive stance; upon their organizational flexibility; and, upon the mobility of their capital resources. In particular, while tourists can be extremely flexible in their choice of destination, particular in the age of low cost airlines and last minute booking, tourism providers and government entities tend to have much greater sunk costs which cannot be easily liquidated and, hence, their level of spatial fixity tends to be much more pronounced.

When evaluating the results presented, a number of the more technical limitations associated with the methodology employed in the study must be recognised and their implications assessed. First, only one general circulation model (GCM) – the Hadley Centre's HadCM3 – was used in the analyses. Although this is one of the most frequently-used GCMs, other models may produce different outcomes. Similarly, only two of dozens of scenarios were considered (the B1A and A1F), though these were carefully selected so as to enable the full range of likely outcomes to be considered.

It is also important to point out that, since our calculations are based on monthly climate normals, they do not allow identification of possible increases in the frequency and/or intensity of extreme weather events, such as heatwaves and floods. Though hard to predict, these extreme events may nevertheless be highly relevant for tourism activity, perhaps even more important than the changes in mean conditions projected by climate models. This is because people experience actual weather conditions rather than climate (“average weather”), and as a result they are far more likely to react to sudden, extreme events that severely impact the physical environment, and can cause substantial damage to tourism infrastructure, than they are scientific projections of climate change.

Finally, as a result of the adoption of the TCI as the primary analysis tool, our study does not take into consideration potential modifications to winter tourism as a result of climate change. As previously examined (by Galloway, 1988; König, 1998; Bicknell and

McManus, 2006; Hennessy et al., 2008; Pickering et al., 2010; Pickering and Buckley, 2010; Pickering, 2011), the outlook for skiing is not positive due to projected reductions in the extent and duration of snow cover. Winter tourists might respond to these changes in a number of manners, from giving up outdoor skiing, to switching to new activities that better suit the new climatic conditions, to travelling further afield to find new ski destinations at which suitable conditions continue to prevail. On the part of winter tourism providers, options include shifting operations upwards, to more snow-reliable levels; transforming themselves into year-round destinations with the addition of spring, summer and fall activity options; seeking government subsidy; or, simply closing down. More detailed consideration of the implications of climate change for winter tourism in Australia is beyond the scope of this paper.

6. Conclusion

This study represents the first known empirical analysis of the potential impacts of climate change on Australia's tourism industry, based on projected shifts in climatic attractiveness for Australia's major tourism destinations over the coming century. As identified, these projected changes have substantial implications for the flows of tourists into and around Australia, as well as for tourism planning, development and management. Tourism businesses – whether in the areas of transportation, accommodations, food and beverage, or events and attractions – are encouraged to review the evidence presented, assess potential impacts on their individual situations, and give priority to the identification and adoption of appropriate adaptation strategies. Similarly, public agencies must anticipate the implications of climate changes as soon as possible and adjust their development and management plans accordingly.

Nevertheless, as noted, the analyses cannot and should not be used to predict changes in the numbers of visitors to Australia, or in the spatial or temporal distribution of those visits, as a result of altered climatic conditions. Additional research is required to assess tourists' likely behavioural reactions to these projected changes, whether using a qualitative or traditional survey-based approach. The contingent behaviour analysis techniques employed by Richardson and Loomis (2005) in their study of the likely impacts of climate change on visitation to Colorado's Rocky Mountain National Park is one appropriate means of assessing potential modifications to tourists' travel patterns and preferences, particularly at specific times or at individual locations.

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TABLE 1. Top inbound markets, destinations (international and domestic, overnight), and activities, among v

Rank	Inbound Markets* (by number of arrivals)		Destinations (overnight visits)#				A
			International Travellers		Domestic Travellers		
	Country	% total arrivals	Destination	% visiting	Destination	% share of visits	
1	New Zealand	20	Sydney	48	Sydney	10	
2	United Kingdom	10	Melbourne	30	Melbourne	9	
3	China	9	Brisbane	17	Brisbane	7	
4	USA	8	Gold Coast	13	Gold Coast	5	
5	Japan	6	Perth	13	North Coast NSW	4	N
6	Singapore	5	Tropical N Queensland	11	South Coast	4	P
7	Malaysia	4	Adelaide	5	Perth	4	V
8	South Korea	3	Sunshine Coast	4	Sunshine Coast	4	
9	Germany	3	Northern Rivers NSW	3	Adelaide	3	Cl
10	India	3	Whitsundays	3	Hunter	3	

* in 2011, # year ending September 2012, + as of December 2006

Source: Tourism Research Australia, 2006, 2012a, 2012c, 2012d.

TABLE 2. TCI classification scheme

Numeric value of index	Description of comfort level for tourism activity
90 – 100	Ideal
80 – 89	Excellent
70 – 79	Very good
60 – 69	Good
50 – 59	Acceptable
40 – 49	Marginal
30 – 39	Unfavourable
20 – 29	Very unfavourable
10 – 19	Extremely unfavourable
Below 9	Impossible

Source: Mieczkowski 1985.