Climate Change and Tourism Features in the Caribbean

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CLIMATE CHANGE AND TOURISM FEATURES IN THE CARIBBEAN

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Abstract[1]

The tourist industry is widely recognised as the key engine of growth in the Caribbean, representing a significant source of foreign exchange earnings and employment. The present study provides an assessment of how climate change could likely impact on regional tourism features. The analysis is undertaken by comparing historical tourism climatic indices to those obtained under the various climate change scenarios. The results suggest that the biggest losers, in terms of deteriorations in their climatic features, are likely to be the Caribbean, Central America and South America.

Keywords*:* Tourism climate index; Climate Change; Caribbean
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1. Introduction

The earth's climate is projected to undergo significant changes during the twenty-first century. The Inter-governmental Panel on Climate Change (IPCC), the United Nation's agency in charge of providing policymakers with an objective source of information about the phenomena, stated in its Fourth Assessment Report 'warming of the climate system is unequivocal' (IPCC, 2007). For the next two decades, a warming of about 0.2^{o}C is expected for the earth's surface. In addition to rising temperatures across the globe, particularly in the northern latitudes, rising sea levels (about 3.3 mm per year) are also forecasted due to thermal expansion, melting glaciers and ice caps as well as polar ice sheets.

These forecasted climatic changes could potentially have implications for the tourist industry in the Caribbean and around the globe. Climate can have physical, physiological and psychological effects for visitors to a destination. For example, the air temperature can make the potential activities of visitors to the Caribbean less enjoyable due to the discomfort of going outdoors. Indeed, Lise and Tol (2002) in an examination of the Organisation for Economic Cooperation and Development (OECD) group of countries reported that visitors tend to prefer temperatures of around 21ºC at their choice of holiday destination. The study therefore suggested that global warming could lead to a shift away from some destinations that either become too hot or too cold.

Given the importance of climate to the sustainability of the tourism industry in the Caribbean, this study attempts to provide an assessment of the likely future implications of climate change for the relative comfort of visitors to the region. The paper calculates the tourism climate index

(TCI) proposed by Mieczkowski (1985) to measure the climatic attractiveness of the destination. The index ranges from from -20 (impossible) to 100 (ideal) and attempts to capture those climatic features that impact on the satisfaction individuals receive from visiting a particular destination. The TCIs are calculated using historical climate data, as well as the most likely climate outcomes under four potential emissions scenarios (IPCC, 2000).

This paper adds to the literature on climate change and tourism in three main areas. First, the study calculates TCIs for a database of 289 countries and provides one of the most comprehensive assessments of the relative attractiveness of various countries as tourist destinations. Second, simulated TCI outcomes are obtained for observations from four climate models and four emissions scenarios, representing 16 potential outcomes. This analysis would provide tourism stakeholders an assessment of the changes in tourism features likely under various climate change scenarios. Finally, the paper gives a comparative assessment of the likely impact of climate change on tourism features within the Caribbean, and relative to other major country groupings and tourist destinations.

The remainder of the paper is organised as follows. Section 2 provides a review of the literature on climate change and tourism. Section 3 then outlines the methodological approach used to calculate the TCIs for the various countries as well as provides a brief description of the database employed. Section 4 analyses the historical as well as forecasted TCIs for the Caribbean as well as other major regional groupings, while Section 5 summaries the main findings of the study and provides some policy recommendations.

2. Literature Review

While long-term changes in climate are high on the global environmental agenda, based on a general understanding of the potential changes in temperature and rainfall patterns that would occur in the coming century, there is still some uncertainty regarding the societal costs of climate change (e.g. Tol, 2002; Stern, 2006). This is a reflection of the problem of modelling the impact of climate change on economic processes and decision-making.

One sector for which this type of analysis is especially critical is tourism. Many tourist activities are dependent on weather conditions, and given the relative ease of adjusting their holiday destinations, an assessment of the future climatic situation is vital for long-term planning. Using the case of Israel's winter sun resort of Eilat, Mansfeld, et al. (2007) assessed the relationship between visitor comfort and climatic conditions. The results suggest that factors such as wind velocity and cloudiness, along with their variability, can have a significant influence on visitor satisfaction. Lise and Tol (2002) investigate how important climate is to the holiday destination choice. The analysis is conducted using both micro and macro data. For the micro-assessment, observations on over 6000 trips of Dutch visitors is used to identify how climate would have impacted on their destination choice as well as holiday activities. On the other hand, the macro-assessment employs time series observations on tourist numbers, destinations, expenditures, and climate of the Organisation for Economic Cooperation and Development (OECD) countries. The macro-assessment suggests that for visitors are attracted to destinations with beaches and a nice climate that varies between 20.6^{o}C and 21.1^{o}C. These macro-based results are quite similar to those obtained from the micro-database. Lise and Tol (2002) note that since individuals chose their destination based on their holiday plans, global warming could lead to significant changes in tourist behaviour.

Given the important role climate can play in visitor destination choice, early studies focussed on developing climate indices based on those found in climatology and human-biometeorology. One of the earliest papers in this area, Davies (1968), developed a measure of weather that is suitable for the summer season. The index is based on the mean daily maximum air temperature, sunshine duration, and total precipitation during the months of June to August. The main problem with this simple index is that it, to some extent oversimplifies the issue of tourism comfort. For example, if it is quite windy at a particular destination, this might offset relatively high temperatures. At some destinations, the best conditions for tourist activities may occur outside of the summer period. In the Caribbean, for example, the tourist season tends to run from December to March of April of the following year. In these situations, summer index is of limited practical value (Yapp & MacDonald, 1978).

More recent literature in the area has attempted to explicitly take account of the interaction between climate and comfort. Terjung (1968) developed a monthly comfort index using subjectively defined categories of comfort. The index was calculated using observations on temperature and relative humidity from 2000 meteorological stations across the globe. Mieczkowski (1985), rather than using ad hoc ratings, assumed that the optimal state for tourist activities was thermal neutrality. The index therefore developed a tourism climate index based on thermal sensation, wind speed, rainfall, and sunshine duration. De Freitas (1990), on the other hand, used the responses of beach users to assess the comfort of at a particular location. The authors found that the optimal temperature tended to be about ‘slightly warm’ and ‘warm’ rather the more commonly assumed thermal neutrality. More recently, de Freitas, et al. (2008) developed a second-generation tourism climate index that is both theoretically sound and empirically tested. Similar to previous indices, the index uses observations on the sky condition, precipitation, wind, and thermal variables. In contrast to previous studies, however, the index is expressed as thermal sensation, ranging from very hot to very cold. Optimal conditions were those that could be classified as slightly warm with clear skies or scattered cloud.

Given the important role that climatic conditions can play in tourist satisfaction and therefore destination choice, evaluating the impact that climate change can have on particular destinations can be of significant use to policymakers and other stakeholders. Harrison, et al. (1999) in their examination of the potential effects of climate change on the Scottish tourist industry combined digital topographic data in a Geographical Information System with more detailed maps of spatial patterns of potential changes in the Scottish climate. The study concluded that climate changes currently taking place have affected the pattern of visitor activity and threatened the financial viability of tourism-related enterprises.

Related to these studies are global models of tourism flows that include temperature as a determinant of the flows of tourists between countries (Berritella, et al., 2004; Hamilton, et al., 2003). Berrittella, et al. (2004) undertook a general equilibrium analysis of climate change impacts on tourism. This paper studied the economic implications of climate-change-induced variations in tourism demand, using a world CGE model. The model is first re-calibrated at some future years, obtaining hypothetical benchmark equilibrium, which are subsequently perturbed by shocks, simulating the effects of climate change. They portray the impact of climate change on tourism by means of two sets of shocks, occurring simultaneously. The first set of shocks translates predicted variations in tourist flows into changes of consumption preferences for domestically produced goods. The second set reallocate income across world regions, simulating the effect of higher or lower tourists' expenditure. Berrittella, et al. (2004) therefore suggests that climate change would ultimately lead to a welfare loss, unevenly spread across regions.

Similarly, Hamilton, et al. (2005) estimated the tourists flow in 207 countries by HTM model (Hamburg Tourism Model) using regional area, population, annual average air temperature, the length of coast and average income. The model is then used to generate scenarios of international tourist departures and arrivals for the period 2000–2075, with particular emphasis on climate change. Hamilton, et al. (2005) predicts that with climate change, preferred destinations would shift to higher latitudes and altitudes. Tourists from temperate climates would spend more holidays in their home countries and therefore decrease worldwide tourism.

Hein (2007) considered the impact of climate change on tourism in Spain. The paper analysed how the suitability of the Spanish climate for tourism will change, and how this will affect tourism flows to Spain. The suitability of the climate for tourists is expressed through an aggregated index, the TCI index. The impacts on tourist flows are modelled using a simple non-linear equation, calibrated on the basis of the current monthly tourism flows in Europe. The model showed that, ceteris paribus, climate change as forecasted with the Hadley model under the IPCC SRES A1 scenario would lead to a reduction of total annual tourist flow to Spain of

20% in 2080 compared to 2004. Similar findings are obtained by Moore (2010) for the Caribbean.

3. Empirical Approach

One of the most important elements of the destination experience is climate. Mieczkowski (1985) conceptualised that tourist destinations are usually characterised by climatic conditions that would be most comfortable for the average visitor. The author therefore developed a tourism climate index (TCI) that was a weighted average of seven (7) climatic variables: (1) monthly means for maximum daily temperature; (2) mean daily temperature; (3) minimum daily relative humidity; (4) mean daily relative humidity; (5) total precipitation; (6) total hours of sunshine, and; (7) average wind speed.[2] Table 1 provides the weights and influence of each of variables used in the calculation of the index.

Table 1: Components of the Tourism Climate Index

Sub-Index	Variables	Influence on TCI	Weight
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%

[2] Each variable was standardised to take values ranging from 5 for optimal to -3 for extremely unfavourable before the index was calculated.

Sunshine (S)	Total hours of sunshine	Positive impact on tourism; (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 calculated TCI ranged from -20 (impossible) to 100 (ideal), with further descriptive rating categories provided in Table 2. The TCI can be an effective tool to assess the supply and quality of climate resources for tourism. However, it can also be used in decision making by travellers and tour operators to select the best time and place, while officials in the industry could use an index to assess a destination for possible tourism development.

Table 2: Rating Categories for Tourism Climate Index

TCI Score	Category
90 to 100	Ideal
80 to 89	Excellent
70 to 79	Very good
60 to 69	Good
50 to 59	Acceptable
40 to 49	Marginal
30 to 39	Unfavourable
20 to 29	Very unfavourable
10 to 19	Extremely unfavourable
-20 to 9	Impossible

The TCI therefore provides researchers with a numerical measure of the effects that climate can have on a visitor's experience. A change in the TCI of the destination or that of its major source countries can therefore have an impact on the demand for travel. The authors employ the approach outlined by Mieczkowski (1985) to calculate the TCI for 289 countries. Following Mieczkowski, the TCI is calculated as follows:

(1) $$TCI = 2[(4xCID) + CIA + (2xP) + (2xS) + W]$$

Data on historical climate outcomes (1961 to 1990) and various climate scenarios are obtained from the Tyndall Centre for Climate Change Research. The database provides projections from four models: (1) the Canadian Centre for Climate Modelling and Analysis Coupled Global Climate Model, CGCM2, (Flato and Boer, 2001); (2) Australia's Commonwealth Scientific and Industrial Research Organisation, CSIRO2, (CSIRO, 1996); (3) Parallel Climate Model, PCM, (Washington, et al., 2000), and; (4) the UK's Meteorological Office Hadley Centre Coupled Model (HADCM3). Four emissions scenarios (A1, A2, B2 and B1) outlined by the IPCC are also examined.

The emissions scenarios assume that the main driving forces of future greenhouse gas trajectories will continue to be demographic change, social and economic development, and the rate and direction of technological change. The A1 and B1 scenarios are based on the low International Institute for Applied Systems Analysis (IIASA) 1996 population projections: the world population is expected to rise to 8.7 billion by 2050 and fall toward 7 billion by 2100 due to a reduction in fertility as well as mortality. In contrast, the B2 scenario uses the long-term United Nation's (UN) Medium 1998 population projection of 10.4 billion by 2100, while the A2 scenario assumes a high population growth of 15 billion by 2100 owing to a significant decline in mortality for most regions (see IPCC, 2000, for greater details). All scenarios exclude surprise or disaster scenarios and do not consider additional climate initiatives, such as the United Nations Framework Convention for Climate Change (UNFCCC) or the emissions targets of the Kyoto Protocol.

The four models and four emission scenarios provide 16 combinations of climate model and emission scenarios that cover 93 percent of the possible range of global climate change envisaged by the IPCC. Since each of the scenarios is just as likely, the average of the 16 scenarios is employed, as well as one standard deviation below and above. These forecasted climate indicators are used to calculate anticipated change in the TCI for 289 countries under investigation.

4. Results

4.1 Historical TCI

Using the methodological approach outlined in the previous section the TCIs for major country groupings are calculated and plotted in Figure 1. The TCIs for most countries show a clear seasonal pattern: for North America, Western and Eastern Europe as well as the Pacific Islands, the time of the year most conducive to tourist activities occurs between May and August, with the peak period occurring in most cases between July and August. In contrast, in the cases of the Caribbean, Middle East, Africa and Asia the favourable times for visiting these regions tend to occur between December and April in any given year. The only outlier region was South America, whose tourism climatic features did not match any other region. Their optimal climatic features occurred during the months of August and November.

The results for the Historical TCI confirm that the best time to visit the Caribbean is between December and April when climatic conditions would rate ‘Good’ and ‘Very Good’, while the remainder of the year would earn ratings of 'Marginal' and 'Acceptable'. The comparative unattractiveness of the May – November period stems from the increase in precipitation received during this period coupled with the rise in temperature associated with the 'summer' months. When ranking the attractiveness of regions based on climatic conditions, the Caribbean has historically ranked third between December and May (behind Central America, the Middle East and Eastern Europe), but falls to eighth and tenth during the June – August and September – November quarters, respectively (see Table 6). The most attractive climate has been that of the Middle East, which historically ranks between first and third, while the most unattractive region has been the Pacific Islands.

Although Figure 1 fits well with the traditional tourist season in the Caribbean, the calculated TCIs for each Caribbean island are quite different. The TCI for each Caribbean island is plotted in Figure 2. Relative to most other Caribbean countries, the TCI for the Bahamas and Cuba was almost u-shaped, with the TCI reaching above 80 in the December to February months and quickly falling off after this period. Indeed, Table 2 shows that during these months the Bahamas are ranked 1 and 2 in terms of their TCI relative to other Caribbean islands. However, between June and September their TCI ranking falls to last and second last amongst the 20 Caribbean islands: during these months their TCIs falls to just above 40, the demarcation between a marginal and unfavourable destination in terms of climate. The main reason behind this significant deterioration was the daytime comfort index, which falls from around 3 during the December to March months to as low as 1 in August.

Even though there is a clear seasonal factor in all the Caribbean countries under investigation, the TCIs for most of the other Caribbean islands did not show any significant decline during the traditional shoulder periods in the region. For example, the TCI for Barbados between December and April ranged from 63 to 72, but only fell to a low of 44 in October. A similar pattern was observed for most of the islands in the region. Due to their relatively flat TCIs, Table 2 shows that the Dominican Republic, St. Kitts and Nevis, Dominica and Haiti had the highest average TCIs for the year as a whole. On the other side of the spectrum, surprisingly the Virgin Islands had the lowest average TCI – due to particularly bad summer months – followed closely by Barbuda, Montserrat and Guadeloupe.

The historical analysis of tourism climatic features in the Caribbean matches fairly closely with the traditional tourist season in the region. Between December and April, the region usually receives more than 60 percent of its visitors for the entire year. This season also matches fairly closely with a deterioration of the TCIs for many North American and Western European nations and therefore explains why most of our visitors emanate from these regions. Given the important role that climatic features can play in terms of determining tourism demand (see Moore, 2009), the following section of this study calculates the TCIs for the Caribbean under various climate change scenarios. The results from this analysis would allow regional policymakers to plan for any potential fallout from a deterioration in tourism climatic features.

4.2 Alternative Scenarios

The forecasted TCIs for the various regional groupings suggest that changes in future climatic conditions could lead to drastic shifts in the tourism season. In general, the TCIs for most regions are likely to deteriorate. The biggest losers, in terms of declines in their tourism features are the Caribbean, Central America and South America: under all four of the potential scenarios, these three regions suffered the greatest relative decline in their TCI. Indeed, under the A1 scenario, the TCIs for these three regions is projected to fall by an average of 20 points: the annual average TCI for this group falls from 58 (Acceptable) to about 38 (Unfavourable).

In contrast, North America, Western Europe as well as Eastern Europe are projected to witness the smallest average declines in their TCIs. Indeed, under the A2 climate change scenario, the TCIs for these three groups is forecasted to rise by between 2-3 points. As a result of these forecasted changes, North America as well as Western and Eastern Europe are likely to become relatively more attractive for tourist activities. Indeed, the average TCI ranking under all of the potential climate change scenarios for Western and Eastern Europe means that these two blocks would now be ranked second and third behind the Middle East, while North America's ranking jumps from eighth to fifth.

Of note, all of the scenarios for the Caribbean show a deterioration in climate conditions in the future, whereas all of the scenarios point to an improvement in the climatic conditions of all of the major source regions for tourists to the Caribbean during the important winter season (December – February). While the TCIs in Caribbean during the 'winter' months still manage to earn ratings of 'marginal' and 'acceptable', the 'summer' months become even more unpleasant, ranging from 'unfavourable' to 'very unfavourable'. This outturn is mainly the result of higher temperatures as well as increased precipitation. The ranking of the Caribbean vis-à-vis the rest of the world deteriorates in line with the worsening of climatic conditions, and the Caribbean increasingly falls into the latter half of the rankings.

At the same time that the Caribbean region is experiencing unfavourable climatic conditions, the conditions in the source markets are improving. The TCI for Northern America and Western Europe improves somewhat during the winter months (these regions start to experience milder winters), though some deterioration is experienced during the height of summer (June – September). The combination of an improved winter season for the main source markets and the deterioration during the same period for the Caribbean translates into very similar TCIs, especially during December – February. This could make tourists indifferent during this period, as climatic conditions in their home countries would be rated similarly as conditions in the Caribbean.

Some of the Caribbean's main competitors also experience changes in their climatic indices. For example, Spain, the second leading tourist destination in the world according to the United Nation World Tourism Organisation, experiences an improvement in climatic conditions during winter months but deteriorates during the summer months. While Mexico, ranked tenth in the world, worsens substantially during winter but improves during summer.

5. Conclusions

The climatic features of the Caribbean have traditionally been one of the comparative advantages of the region as a tourist destination. Based on a survey of 338 individuals, Uyarra, et al. (2005) reports that warm temperatures, clear waters, and low health risks were the main environmental features important to visitors to Bonaire and Barbados. Visitors to Bonaire, however, placed more emphasis on marine wildlife attributes while those to Barbados reported that beach characteristics were more important.

Given the importance of climate to visitors to the region, this study employs Mieczkowski's (1985) TCI to evaluate the relative historical attractiveness of the Caribbean. The TCI is also calculated for four of the most likely climate change scenarios to provide policymakers in the region a projection of how climate change could potentially affect the region's tourism industry. To evaluate the potential effect of not just potential substitution effects within the region, but outside of the region as well, the TCIs are calculated for major country groupings as well as the most popular tourism destinations according to the World Tourism Organisation.

The results for the Historical TCI validated that the December to April period was the best time to visit the Caribbean. During this period, climatic conditions would usually rate as 'Good' or 'Very Good', while the remainder of the year would earn ratings of 'Marginal' and 'Acceptable'. The deterioration in the TCI during the May – November period stemmed from higher temperatures as well as increased precipitation. Historically, at the global level the Caribbean has historically ranked third between December and May (behind Central America, the Middle East and Eastern Europe), and between eighth and tenth during the June – August and September – November quarters, respectively.

The climatic features of the Caribbean, however, could undergo significant changes as a result of climate change. To evaluate the effects of these changes projected climate indicators from four climate models and four emissions scenarios are used to calculated forecasted TCIs for world and the Caribbean in particular for the end of the century. Under all four of the likely climate change scenarios, the calculated TCIs decline in every major regional country grouping. The biggest losers, in terms of dwindling TCIs are the Caribbean, Central America and South America. While the TCIs in Caribbean during the 'winter' months still manage to earn ratings of 'marginal' and 'acceptable', the 'summer' months become even more unpleasant, ranging from 'unfavourable' to 'very unfavourable'. This outturn is mainly the result of higher temperatures as well as increased precipitation. The ranking of the Caribbean vis-à-vis the rest of the world deteriorates in line with the worsening of climatic conditions, and the Caribbean increasingly falls into the latter half of the rankings.

References

Berritella, M., et al., 2004. A general equilibrium analysis of climate change impacts on tourism. Centre for Marine and Atmospheric Science, Hamburg. Working Paper FNU-49.

CSIRO, 1996. Climate change scenarios for the Australian region. Climate Impact Group, CSIRO Division of Atmospheric Research, Melbourne.

Davies, N.E., 1968. An optimum summer weather index. *Weather*, 23, pp. 305-317.

De Freitas, C., 1990. Recreation climate assessment. *International Journal of Climatology*, 10(), pp. 89-103.

De Freitas, C.R., Scott, D. & McBoyle, G., 2008. A second generation climate index for tourism (CIT): specification and verification. *International Journal of Biometeorology*, 52(5), pp. 399-407.

Flato, G.M. & Boer, G.J., 2001. Warming asymmetry in climate change simulations. *Geophysical Research Letters*, 28(1), pp. 195-198.

Hamilton, J.M., Maddison, D.J. & Tol, R.S.J., 2003. Climate change and international tourism: a simulation study. Centre for Marine and Climate Research, Hamburg University, Hamburg. Working Paper FNU-31.

Hamilton, J.M., Maddison, D.J. & Tol., R.S.J., 2005. Climate change and international tourism: a simulation study. *Global Environmental Change*, 15(3), pp. 253-266.

Harrison, S., Winterbottom, S. & Sheppard, C., 1999. The potential effects of climate change on the Scottish tourist industry. *Tourism Management*, 20(2), pp. 203-211.

Hein, L., 2007. The impact of climate change on tourism in Spain. Centre for International Climate and Environmental Research, Oslo. CICERO Working Paper 2007:2.

IPCC, 2000. *Special Report on Emissions Scenarios.* [Online] Intergovernmental Panel on Climate Change. Available at: www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf.

IPCC, 2007. Fourth Assessment Report. [Online] Intergovernmental Panel on Climate Change. Available at: www1.ipcc.ch/ipccreports/assessments-reports.htm.

Lise, W. & Tol, R.S.J., 2002. Impact of climate on tourist demand. *Climatic Change*, 55(4), pp. 429-449.

Mansfeld, Y., Freundlich, A. and Kutiel, H., 2007. The relationship between weather conditions and tourists' perception of comfort: the case of the winter sun resort of Eilat. In: B. Amelung, K. Blazejczyk & K. Matzarakis, eds. *Climate change and tourism – assessment and coping strategies*. Maastricht, pp. 116-139.

Mieczkowski, Z., 1985. The tourism climatic index: a method of evaluating world climates for tourism,' *Canadian Geographer* 29: 220-233.

Moore, W., 2010. The impact of climate change on Caribbean tourism demand. *Current Issues in Tourism*, forthcoming.

Stern, N. et al., 2006. *Stern review: the economics of climate change*. London: HM Treasury.

Terjung, W.H., 1968. World patterns of the distribution of the monthly climate index. *International Journal of Biometeorology*, 12(), pp. 119-151.

Tol, R.S.J., 2002. Welfare specifications and optimal control of climate change: an application of fund. *Energy Economics*, 24(4), pp. 367-376.

Uyarra, M.C., et al. 2005. Island-specific preferences of tourists for environmental features: implications of climate change for tourism-dependent states. *Environmental Conservation*, 32(1), pp. 11-19.

Washington, W.M., et al., 2000. Parallel climate model (PCM) control and transient simulations. *Climate Dynamics*, 16(10-11), pp. 755-74.

Yapp, G.A. & McDonald, N.S., 1978. A recreation climate model. *Journal of environmental management*, 7(3), pp. 235-252.

Table 1: Historical TCIs

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	43.9	42.3	45.8	53.1	58.3	60.0	63.0	64.5	54.3	52.1	48.9	41.8
Central America	73.3	75.0	71.8	63.5	49.8	44.8	46.1	45.8	44.1	52.1	62.4	70.1
South America	55.3	55.5	56.2	54.9	55.5	56.1	60.3	62.8	63.1	61.0	61.7	56.7
Caribbean	**69.9**	**73.1**	**71.0**	**63.9**	**52.5**	**48.4**	**48.8**	**45.4**	**44.2**	**46.4**	**53.0**	**64.1**
Western Europe	40.0	44.3	49.5	57.8	68.4	75.7	76.9	75.8	71.1	59.9	45.9	40.5
Eastern Europe	37.0	41.3	48.7	61.9	79.6	83.6	82.6	82.6	80.0	64.2	47.3	38.1
Middle East	67.6	70.6	75.9	76.9	71.5	66.7	63.8	66.3	70.3	76.1	78.3	71.2
Africa	67.7	65.5	61.9	61.3	61.1	63.5	62.6	61.6	60.2	62.2	66.4	67.8
Asia	62.3	61.2	57.6	51.3	46.6	41.8	39.4	39.0	45.8	49.2	56.0	60.8
Pacific Islands	39.0	40.2	38.8	44.1	48.1	53.1	53.7	55.1	52.7	48.8	45.1	41.5

Table 2: TCIs for A1 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	47.3	48.8	45.5	53.8	57.3	51.5	52.3	53.0	51.5	51.5	48.5	46.5
Central America	53.9	54.5	48.6	41.5	30.9	23.6	25.4	26.9	21.5	28.0	42.8	50.4
South America	36.7	38.8	37.5	38.6	39.9	41.7	45.7	46.3	45.9	43.7	40.7	38.7
Caribbean	**49.8**	**51.9**	**50.7**	**43.0**	**33.8**	**29.7**	**30.2**	**25.7**	**24.4**	**26.2**	**31.8**	**43.9**
Western Europe	42.9	48.0	52.0	60.2	69.5	71.2	66.3	65.2	68.4	63.0	49.3	44.2
Eastern Europe	41.7	45.6	54.3	67.6	77.2	71.9	62.1	62.7	73.9	69.7	51.2	42.1
Middle East	69.4	71.3	71.7	68.3	59.5	52.1	49.0	50.7	56.9	63.5	70.9	70.8
Africa	51.8	49.9	47.4	46.7	47.6	49.6	48.9	47.3	45.8	46.6	50.0	52.3
Asia	54.6	53.2	49.0	42.5	36.3	27.5	23.5	22.3	29.4	39.3	47.7	52.2
Pacific Islands	24.8	24.0	24.3	29.3	34.5	38.9	41.0	43.1	38.7	35.4	30.4	27.7

Table 3: TCIs for A2 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	50.6	47.3	49.0	57.4	60.5	56.8	61.0	62.3	53.0	55.6	50.1	49.3
Central America	62.3	63.3	59.5	51.0	37.5	32.0	34.0	35.3	32.4	39.6	51.3	60.4
South America	44.8	46.2	45.5	45.5	46.7	48.1	52.2	53.3	54.4	51.8	50.4	46.9
Caribbean	**58.8**	**60.9**	**60.1**	**52.8**	**42.3**	**38.2**	**39.0**	**34.0**	**32.6**	**34.7**	**41.8**	**52.1**
Western Europe	43.8	49.3	53.9	62.8	74.7	77.8	74.0	72.6	75.1	66.7	50.9	45.1
Eastern Europe	42.4	46.6	55.7	69.8	84.1	79.4	70.2	70.4	81.8	72.7	52.3	42.3
Middle East	72.7	75.2	76.5	72.3	64.2	57.7	54.7	56.2	63.1	68.7	76.2	75.3
Africa	58.2	56.4	52.8	52.5	52.9	55.4	54.2	52.7	51.4	51.9	56.5	58.6
Asia	59.4	56.1	52.9	46.6	42.2	33.9	29.0	28.6	35.8	44.2	50.7	56.0
Pacific Islands	29.3	29.3	30.0	34.4	39.7	44.7	47.1	47.3	44.3	40.1	35.0	32.3

Table 4: TCIs for B1 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	46.3	46.3	45.0	50.8	55.8	54.5	56.3	52.3	52.8	51.5	47.5	44.8
Central America	58.8	60.3	54.4	46.1	34.3	31.5	31.0	31.9	30.1	36.5	47.9	56.1
South America	42.4	44.1	43.4	44.3	43.8	47.5	50.1	51.7	52.4	47.2	45.7	43.6
Caribbean	**56.3**	**58.3**	**56.4**	**48.6**	**38.7**	**35.0**	**35.1**	**29.9**	**29.7**	**31.6**	**38.1**	**49.6**
Western Europe	41.4	46.0	50.4	57.6	67.1	71.4	70.0	68.8	68.4	59.9	47.3	42.1
Eastern Europe	39.3	43.8	51.2	62.1	75.3	75.9	69.7	70.1	74.3	65.5	49.2	40.4
Middle East	67.3	70.9	71.0	71.3	62.1	55.4	51.9	54.5	61.1	66.9	72.6	69.8
Africa	57.7	55.3	52.5	51.1	51.5	53.3	53.4	51.9	50.3	51.4	56.4	57.9
Asia	57.5	54.8	51.4	44.9	38.4	31.7	28.8	29.1	34.5	42.7	50.2	54.8
Pacific Islands	28.1	29.7	30.6	34.3	39.5	44.1	45.8	46.2	43.0	39.6	34.7	30.2

Table 5: TCIs for B2 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	46.3	45.3	45.0	51.3	55.8	52.5	56.5	53.0	52.0	51.0	47.5	45.3
Central America	58.5	59.3	54.4	46.3	32.6	29.6	30.3	32.6	28.3	35.4	46.3	55.9
South America	40.8	42.5	41.5	43.1	42.8	46.5	49.2	49.9	50.8	47.8	45.0	43.2
Caribbean	**54.3**	**57.2**	**55.5**	**47.6**	**38.1**	**33.9**	**33.5**	**29.0**	**28.2**	**30.4**	**36.0**	**48.0**
Western Europe	41.5	46.4	50.8	57.8	67.7	71.1	69.6	68.2	68.8	59.9	47.4	42.4
Eastern Europe	40.0	44.3	51.9	64.3	75.8	75.3	67.7	68.2	75.8	66.1	49.2	39.9
Middle East	67.6	70.3	71.4	70.5	61.9	54.6	52.3	53.9	60.9	66.3	72.5	69.7
Africa	55.7	54.2	51.7	50.2	50.2	52.9	52.6	51.1	49.2	50.4	55.2	57.1
Asia	57.5	54.8	50.7	44.8	38.6	31.3	28.7	27.8	33.4	42.1	49.7	54.8
Pacific Islands	27.1	28.9	28.6	33.3	38.5	42.7	44.6	46.1	43.0	38.6	33.4	30.3

Table 6: Ranking in terms of Historical TCI

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	7	8	9	8	5	5	4	4	6	6	7	7
Central America	1	1	2	3	8	9	9	8	10	6	3	2
South America	6	6	6	7	6	6	6	5	4	4	4	6
Caribbean	**2**	**2**	**3**	**2**	**7**	**8**	**8**	**9**	**9**	**10**	**6**	**4**
Western Europe	8	7	7	6	3	2	2	2	2	5	9	9
Eastern Europe	10	9	8	4	1	1	1	1	1	2	8	10
Middle East	4	3	1	1	2	3	3	3	3	1	1	1
Africa	3	4	4	5	4	4	5	6	5	3	2	3
Asia	5	5	5	9	10	10	10	10	8	8	5	5
Pacific Islands	9	10	10	10	9	7	7	7	7	9	10	8

Table 7: Ranking based on the A1 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	6	6	8	4	4	4	3	3	4	4	5	5
Central America	3	2	6	8	10	10	9	8	10	9	7	4
South America	9	9	9	9	6	6	6	6	5	6	8	9
Caribbean	**5**	**4**	**4**	**6**	**9**	**8**	**8**	**9**	**9**	**10**	**9**	**7**
Western Europe	7	7	3	3	2	2	1	1	2	3	4	6
Eastern Europe	8	8	2	2	1	1	2	2	1	1	2	8
Middle East	1	1	1	1	3	3	4	4	3	2	1	1
Africa	4	5	7	5	5	5	5	5	6	5	3	2
Asia	2	3	5	7	7	9	10	10	8	7	6	3
Pacific Islands	10	10	10	10	8	7	7	7	7	8	10	10

Table 8: Ranking based on the A2 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	6	7	8	4	4	4	3	3	5	4	8	6
Central America	2	2	3	7	10	10	9	8	10	9	4	2
South America	7	9	9	9	6	6	6	5	4	6	7	7
Caribbean	**4**	**3**	**2**	**5**	**7**	**8**	**8**	**9**	**9**	**10**	**9**	**5**
Western Europe	8	6	5	3	2	2	1	1	2	3	5	8
Eastern Europe	9	8	4	2	1	1	2	2	1	1	3	9
Middle East	1	1	1	1	3	3	4	4	3	2	1	1
Africa	5	4	7	6	5	5	5	6	6	5	2	3
Asia	3	5	6	8	8	9	10	10	8	7	6	4
Pacific Islands	10	10	10	10	9	7	7	7	7	8	10	10

Table 9: Ranking based on the B1 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	6	6	8	5	4	4	3	4	4	4	6	6
Central America	2	2	3	7	10	10	9	8	9	9	5	3
South America	7	8	9	9	6	6	6	6	5	6	8	7
Caribbean	**5**	**3**	**2**	**6**	**8**	**8**	**8**	**9**	**10**	**10**	**9**	**5**
Western Europe	8	7	7	3	2	2	1	2	2	3	7	8
Eastern Europe	9	9	6	2	1	1	2	1	1	2	4	9
Middle East	1	1	1	1	3	3	5	3	3	1	1	1
Africa	3	4	4	4	5	5	4	5	6	5	2	2
Asia	4	5	5	8	9	9	10	10	8	7	3	4
Pacific Islands	10	10	10	10	7	7	7	7	7	8	10	10

Table 10: Ranking based on the B2 Scenario

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
North America	6	7	8	4	4	5	3	4	4	4	5	6
Central America	2	2	3	7	10	10	9	8	9	9	7	3
South America	8	9	9	9	6	6	6	6	5	6	8	7
Caribbean	**5**	**3**	**2**	**6**	**9**	**8**	**8**	**9**	**10**	**10**	**9**	**5**
Western Europe	7	6	6	3	2	2	1	1	2	3	6	8
Eastern Europe	9	8	4	2	1	1	2	2	1	2	4	9
Middle East	1	1	1	1	3	3	5	3	3	1	1	1
Africa	4	5	5	5	5	4	4	5	6	5	2	2
Asia	3	4	7	8	7	9	10	10	8	7	3	4
Pacific Islands	10	10	10	10	8	7	7	7	7	8	10	10

Figure 1: Historical TCIs for Six Major Regions

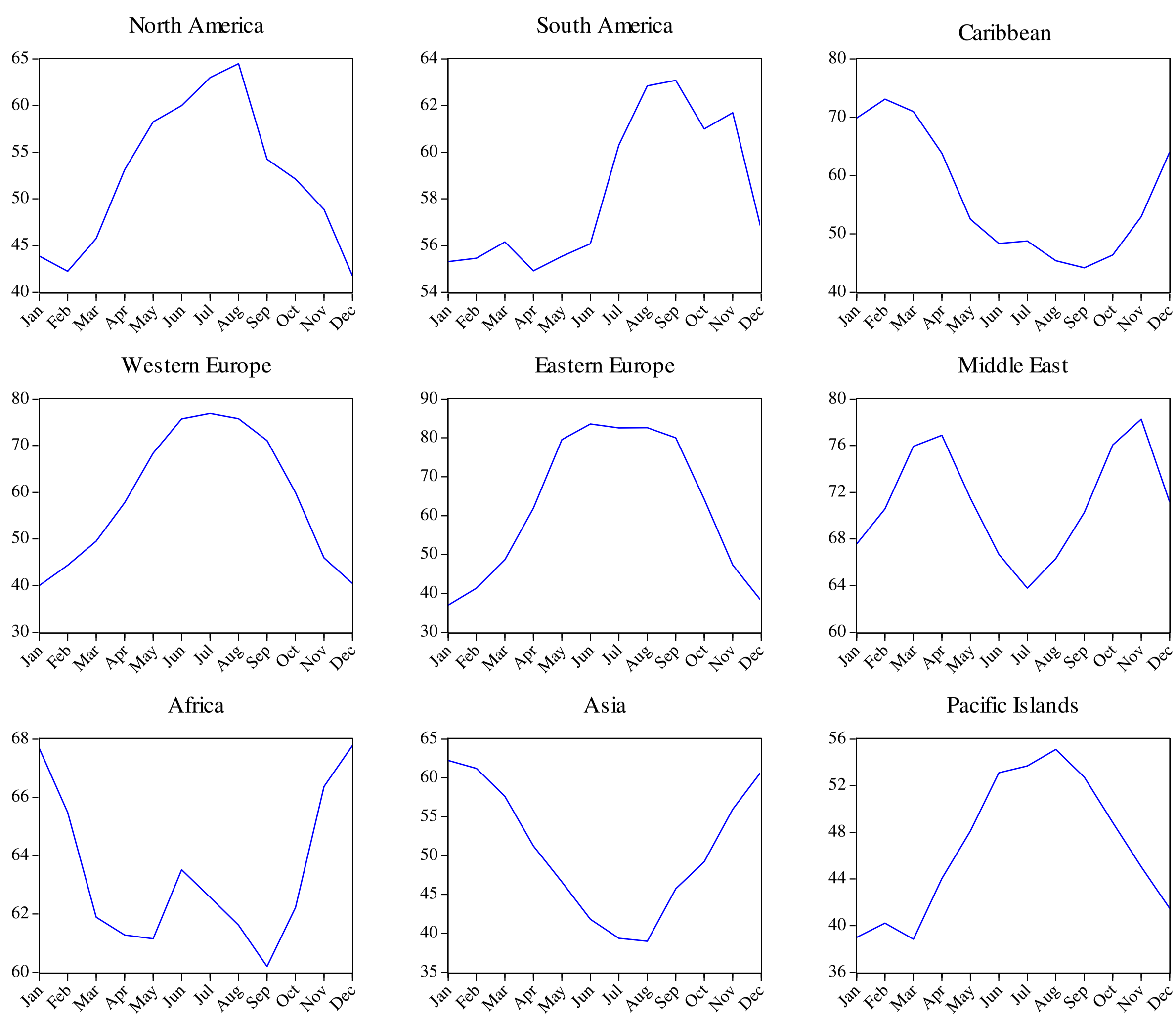

Figure 2: Historical TCIs for the Caribbean

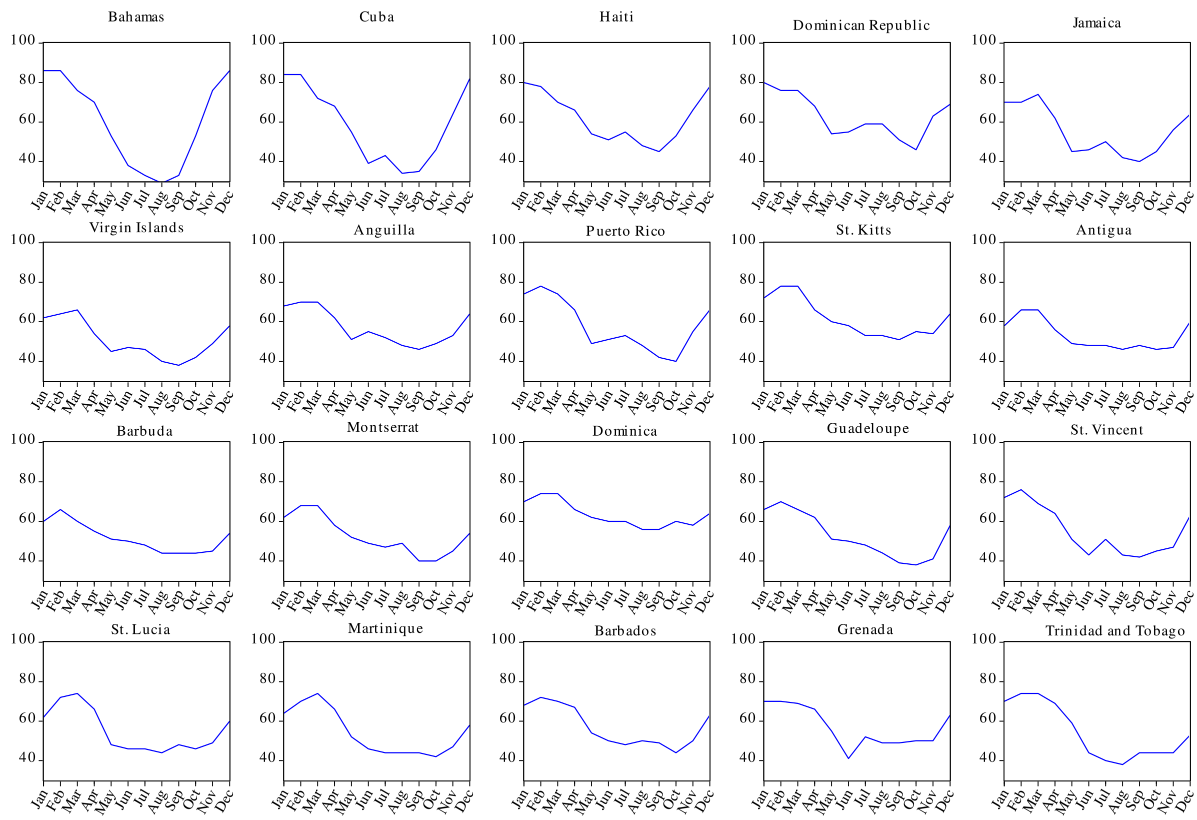

Figure 3: Forecasted TCI for the Caribbean

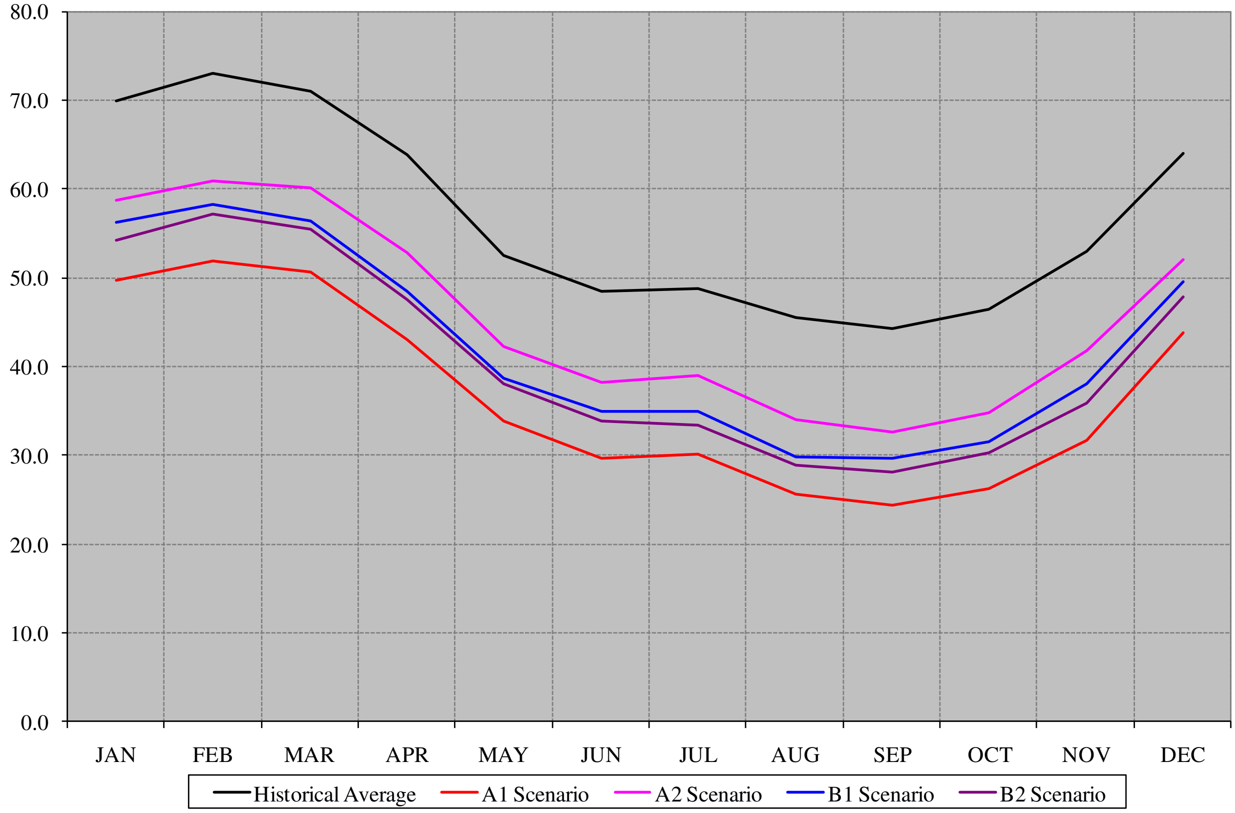

Figure 4: Forecasted TCI for Western Europe

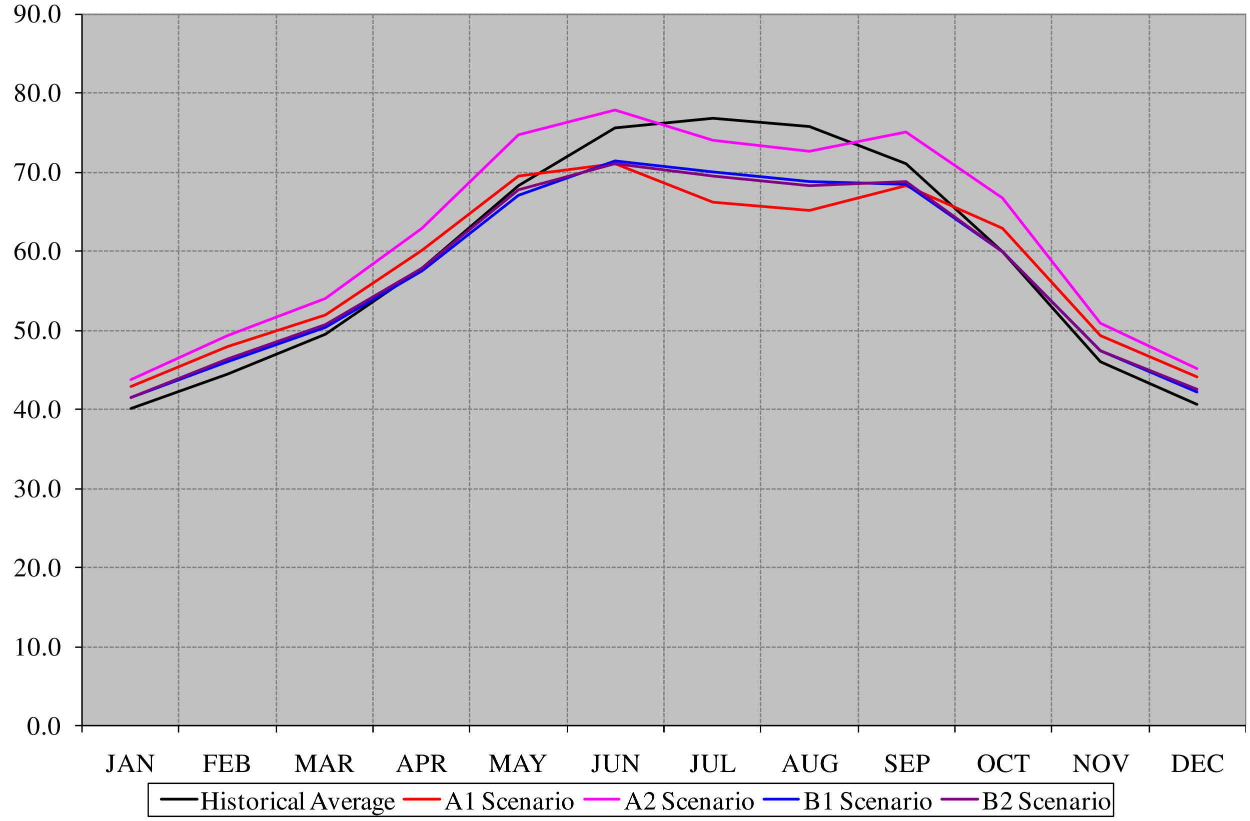

Figure 5: Forecasted TCI for North America

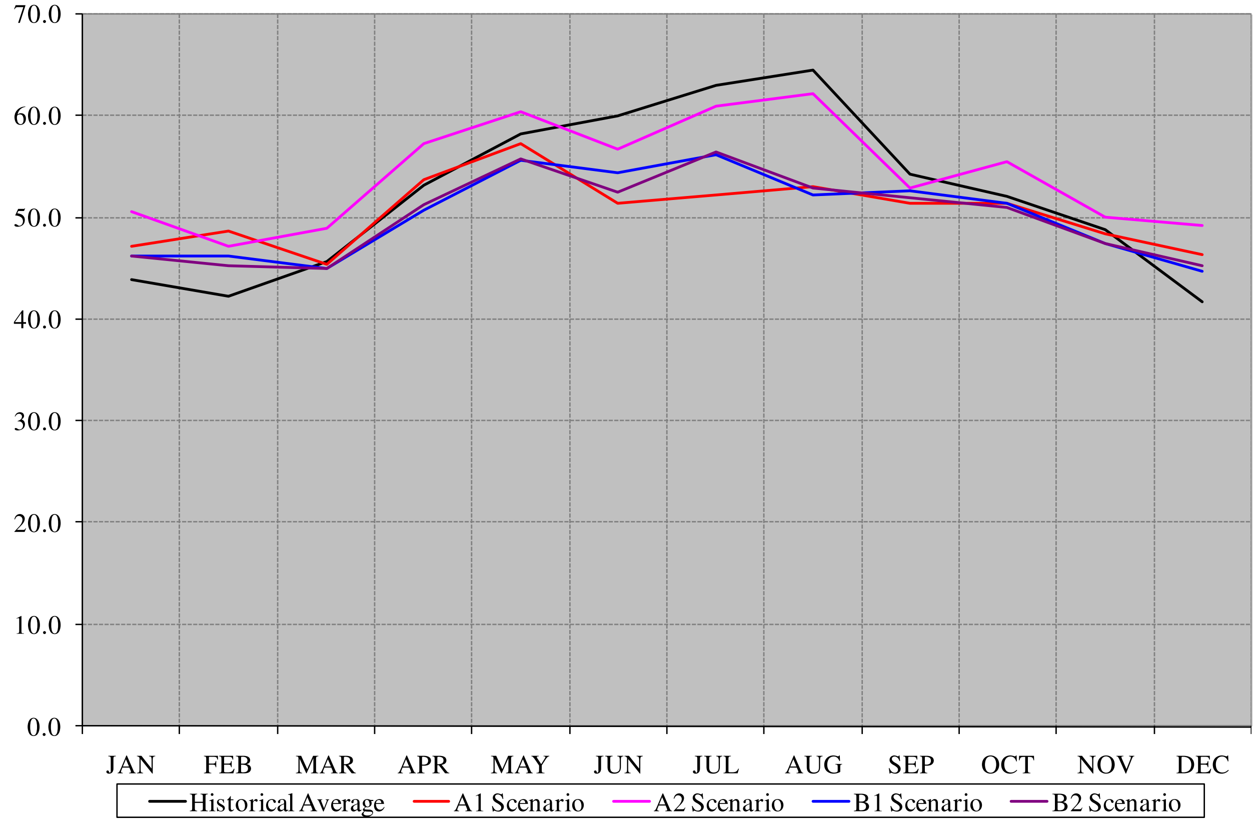

Figure 5: Forecasted TCI for Mexico

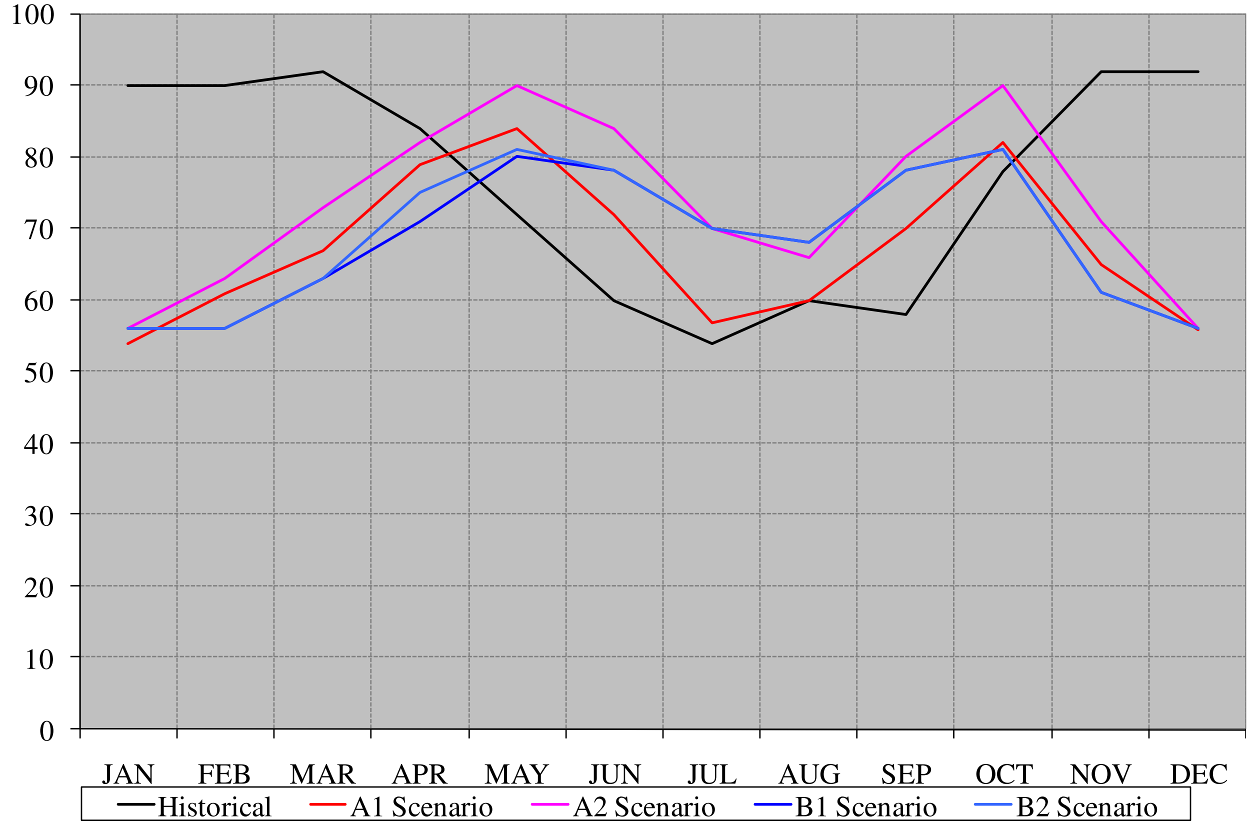

Figure 6: Forecasted TCI for Spain