



Economic Commission for Latin America and the Caribbean
Subregional Headquarters for the Caribbean

LIMITED
LC/CAR/L.307
22 October 2011
ORIGINAL: ENGLISH

AN ASSESSMENT OF THE ECONOMIC IMPACT OF CLIMATE CHANGE ON THE TOURISM SECTOR IN MONTSERRAT

This document has been reproduced without formal editing.

Acknowledgement

The Economic Commission for Latin America and the Caribbean (ECLAC) Subregional Headquarters for the Caribbean wishes to acknowledge the assistance of Winston Moore, Consultant, in the preparation of this report.

Table of Contents

| | | |
|------|---|-------------------------------------|
| I. | INTRODUCTION..... | 1 |
| II. | BACKGROUND..... | 4 |
| | A. ECONOMIC REVIEW..... | 5 |
| | B. TRANSPORTATION COSTS | 7 |
| | C. REVIEW OF LITERATURE..... | 8 |
| | D. CLIMATIC PATTERNS | 11 |
| | E. EXTREME EVENTS | 13 |
| | F. BEACHES AND CORAL REEFS..... | 14 |
| III. | DATA COLLECTION AND ANALYSIS | 16 |
| | A. TOURIST ARRIVALS..... | 16 |
| | B. CLIMATE CHANGE AND TOURISM FEATURES..... | 16 |
| IV. | QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON TOURISM | 20 |
| | A. TRAVEL DEMAND..... | 20 |
| | B. SPECIES, ECOSYSTEMS AND LANDSCAPES | 21 |
| | C. LAND LOSS..... | 21 |
| | D. DISCOUNT RATE AND BUSINESS AS USUAL SCENARIO..... | 22 |
| V. | ECONOMETRIC RESULTS AND SIMULATIONS | 22 |
| VI. | COST- BENEFIT ASSESSMENT OF ADAPTATION OPTIONS | 27 |
| | A. CURRENT ATTEMPTS AT ADAPTATION | 27 |
| | B. POTENTIAL ADAPTATION MEASURES | 27 |
| | C. COST-BENEFIT ANALYSIS OF SHORT-LISTED OPTIONS..... | 34 |
| VII. | CONCLUSIONS..... | 35 |
| | ANNEX | Error! Bookmark not defined. |
| | REFERENCES..... | 42 |

List of Figures

| | |
|--|----|
| Figure 1: Visitor expenditure under various climate change scenarios | v |
| Figure 2: Map of Montserrat..... | 1 |
| Figure 3: Breakdown of Real Value-Added in Montserrat (2009)..... | 1 |
| Figure 4: Breakdown of stay-over visitor arrivals for Montserrat..... | 1 |
| Figure 5: The Equatorial Pacific Ocean..... | 9 |
| Figure 6: Historical average daily temperature Montserrat..... | 12 |
| Figure 8: Intensity of Caribbean hurricanes..... | 14 |
| Figure 9: Long-stay tourist arrivals in Montserrat..... | 16 |
| Figure 10: Historical TCI for Montserrat (1980-2009)..... | 19 |
| Figure 11: Projected TCI for Montserrat 2025 and 2050..... | 19 |
| Figure 12: Historical average daily maximum temperature- Montserrat..... | 37 |
| Figure 13: Historical average daily relative humidity- Montserrat..... | 38 |
| Figure 14: Historical average monthly precipitation- Montserrat..... | 38 |
| Figure 15: Historical average sun duration- Montserrat..... | 39 |

List of Tables

| | |
|--|----|
| Table 1: Climate and the Potential Impact on Tourism..... | 2 |
| Table 2: Indicative Airfares for Montserrat from Major Cities..... | 7 |
| Table 3: Extreme Events in Montserrat | 14 |
| Table 4: Components of the Tourism Climate Index | 17 |
| Table 5: Rating Categories for Tourism Climate Index..... | 17 |
| Table 6: Long-Run Regression Estimates..... | 23 |
| Table 7: Forecasted Arrivals under Various Climate Change Scenarios..... | 24 |
| Table 8: Value of Coral Reef Affected..... | 25 |
| Table 9: Impacts of Sea Level Rise on Infrastructure | 25 |
| Table 10: Annual and Capital Costs of Sea Level Rise | 26 |
| Table 11: Estimated Value of Land Loss Due to Sea Level Rise | 26 |
| Table 12: Total Estimated Impact of Climate Change on Tourism (US\$ Mil) | 27 |
| Table 13: Potential Risks and Adaptation Options..... | 28 |
| Table 14: Benefit-Cost Analysis of Selected Options | 35 |
| Table 15: Details of Cost-Benefit Scenarios..... | 40 |

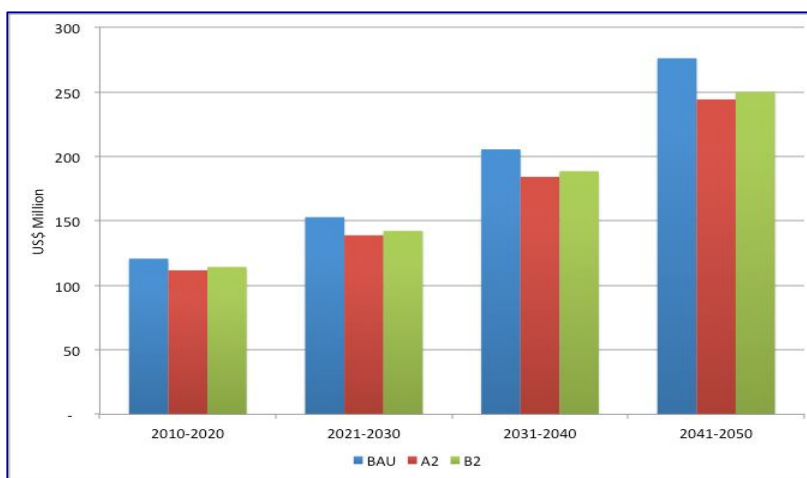
Executive Summary

This report provides an analysis and evaluation of the likely effects of climate change on the tourism sector in Montserrat. Clayton (2009) identifies three reasons why the Caribbean should be concerned about the potential effects of climate change on tourism: (a) the relatively high dependence on tourism as a source of foreign exchange and employment; (b) the intrinsic vulnerability of small islands and their infrastructure (e.g. hotels and resorts) to sea level rise and extreme climatic events (e.g. hurricanes and floods); and, (c) the high dependence of the regional tourist industry on carbon-based fuels (both to bring tourist to the region as well as to provide support services in the region).

The effects of climate change are already being felt on the island. Between 1970 and 2009, there was a rise in the number of relatively hot days experienced on the island. Added to this, there was also a decline in mean precipitation over the period. Besides temperature, there is also the threat of wind speeds. Since the early 20th century, the number of hurricanes passing through the Caribbean has risen from about 5-6 per year to more than 25 in some years of the twenty-first century. In Montserrat, the estimated damage from four windstorms (including hurricanes) affecting the island was US\$260 million or almost five times 2009 gross domestic product (GDP). Climate change is also likely to significantly affect coral reefs. Hoegh-Guldberg (2007) estimates that should current concentrations of carbon dioxide in the Earth's atmosphere rise from 380ppm to 560ppm, decreases in coral calcification and growth by 40% are likely.

The report attempted to quantify the likely effects of the changes in the climatic factors mentioned above. As it relates to temperature and other climatic variables, a tourism climatic index that captures the elements of climate that impact on a destination's experience was constructed. The index was calculated using historical observations as well as those under two likely climate scenarios: A2 and B2. The results suggest that under both scenarios, the island's key tourism climatic features will likely decline and therefore negatively impact on the destination experience of visitors. Including this tourism climatic index in a tourism demand model suggests that this would translate into losses of around 145% of GDP (see Figure 1).

Figure 1: Visitor expenditure under various climate change scenarios



Source: Data compiled by author

As it relates to coral reefs, the value of the damage due to the loss of coral reefs was estimated at 7.6 times GDP, while the damage due to land loss for the tourism industry was 45% of GDP. The total cost of climate change for the tourism industry was therefore projected to be 9.6 times 2009 GDP over a 40-year horizon.

Given the potential for significant damage to the industry, a large number of potential adaptation measures were considered. Out of these, a short-list of 9 potential options was selected using 10 evaluation criteria. These included:

- (a) Increasing recommended design wind speeds for new tourism-related structures;
- (b) Construction of water storage tanks;
- (c) Irrigation network that allows for the recycling of waste water;
- (d) Enhanced reef monitoring systems to provide early warning alerts of bleaching events;
- (e) Deployment of artificial reefs and fish-aggregating devices;
- (f) Developing national evacuation and rescue plans;
- (g) Introduction of alternative attractions;
- (h) Providing re-training for displaced tourism workers, and;
- (i) Revised policies related to financing national tourism offices to accommodate the new climatic realities

Using cost-benefit analysis, three options were put forward as being financially viable and ready for immediate implementation:

- (a) Increase recommended design speeds for new tourism-related structures;
- (b) Enhance reef monitoring systems to provide early warning alerts of bleaching events, and;
- (c) Deploy artificial reefs or fish-aggregating devices.

While these options had positive benefit cost ratios, other options were also recommended based on their non-tangible benefits: an irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

I. INTRODUCTION

Most Caribbean countries have embraced tourism as one of the key planks of their development strategy. The main motivations behind this approach relate to the advantages the industry provides relative to other exports of goods and services. First, it allows the destination to obtain economic benefits from characteristics that normally could not be traded, for example, natural and other cultural attractions. Second, locally produced goods can be sold at a premium to visitors. Finally, goods that could not be exported due to insufficient export capability can be sold to tourists (Mihalic, 2002). As a result of these characteristics, the industry accounts for one third of all trade, a quarter of foreign exchange receipts and one fifth of total employment in the Caribbean (de Albuquerque & McElroy, 1995). Numerous authors have also attributed most of the region's growth to the industry (Latimer, 1985; Modeste, 1995). Bishop (2010), however, argues that the shift to tourism as a key plank of the region's development strategy was not a strategy decision, but one pressed upon the region given dwindling alternatives. This situation reflects the deteriorating options available due to the decline of preferential access to traditional metropolitan markets for agricultural goods.

Given the recent shift in development objectives, the potential impact of global climatic changes has been put on the front burner. Pachauri and Reisinger (2007) defined climate change as changes "in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer." The period 1995 to 2006 has provided 12 of the warmest years since instrumental recording began in 1850. In addition, the linear trend warming over the period 1956 to 2005 was almost twice that for the 100 years from 1906 to 2005. Increases in global temperatures, through thermal expansion and the melting glaciers, are also pushing up sea levels around the world. Global average sea levels rose by about 1.8 mm per year between 1961 and 2003 and at an average rate of around 3.1 mm from 1993 to 2003.

There is also an intimate link between climate and tourism. Climate's impact on tourism can be physical, physiological and psychological (Table 1). For example, increased rain or high wind implies that the visitor may have to delay the chance to visit some particular attraction or pursue some activity of interest. Other factors falling into this category might be severe weather, air quality and ultraviolet radiation. In terms of the physiological and psychological aspects of visitor satisfaction, factors such as high air temperature and blue skies may affect environmental stress, hyperthermia and general enjoyment or attractiveness of the destination.

Table 1:
Climate and the potential impact on tourism

| FACET OF CLIMATE | SIGNIFICANCE | IMPACT |
|---|---|---|
| Aesthetic | | |
| Sunshine/cloudiness | Quality of experience | Enjoyment, attractiveness of site |
| Visibility | Quality of experience | Enjoyment, attractiveness of site |
| Day length | Convenience | Hours of daylight available |
| | | |
| Physical | | |
| Wind | Annoyance | Blown belongings, sand and dust |
| Rain | Annoyance, charm | Wetting, reduced visibility and enjoyment |
| Snow | Winter sports/activities | Participation in sports/activities |
| Ice | Danger | Personal injury, damage to property |
| Severe weather | Annoyance, danger | All of the above |
| Air quality | Annoyance, danger | Health, physical wellbeing, allergies |
| Ultraviolet radiation | Danger, attraction | Health, suntan, sunburn |
| | | |
| Thermal | | |
| Integrated effects of air temperature, wind, solar radiation, humidity, long wave radiation, metabolic rate | Thermal comfort, therapeutic, restorative | Environmental stress, Physiological strain, hypothermia, hyperthermia, potential for recuperation |

Source: de Freitas (2003)

Although the climatic features of a destination may influence visitor satisfaction, it is unclear whether or not individuals pay attention to this factor when planning their trip. Hamilton and Lau (2005), therefore, examine this issue through the use of a self-administered questionnaire distributed at the airport, international bus stations and train stations in Germany. The results of the questionnaire suggest that the majority (73%) of visitors tends to inform themselves in relation to the climate of a destination, with 42% doing so before they make their travel arrangements. Uyarra et al. (2005) undertook a similar analysis for visitors to the islands of Bonaire and Barbados. Based on a survey of 338 individuals, the study found that warm temperatures, clear waters and low health risks were the main environmental features important to visitors to these islands. Visitors to Bonaire, however, placed more emphasis on marine wildlife attributes while those to Barbados reported that beach characteristics were more important. To evaluate the impact of climate, Uyarra et al. (2005) also solicited responses in relation to re-visit probability in the event of coral bleaching and sea level rise. In this regard, the study found that 80% of tourists reported that they would not return to the island in the event of these occurrences.

Clayton (2009) identifies three reasons why the Caribbean should be concerned about the potential effects of climate change on tourism: (a) the relatively high dependence on tourism as a source of foreign exchange and employment; (b) the intrinsic vulnerability of small islands and their infrastructure (e.g. hotels and resorts) to sea level rise and extreme climatic events (e.g. hurricanes and floods); and, (c) the high dependence of the regional tourist industry on carbon-based fuels, both to bring tourists to the region as well as to provide support services. Clayton argues that the sustainability of the industry in the region will depend on the extent to which participants are willing to take bold steps, for example, move hotels back

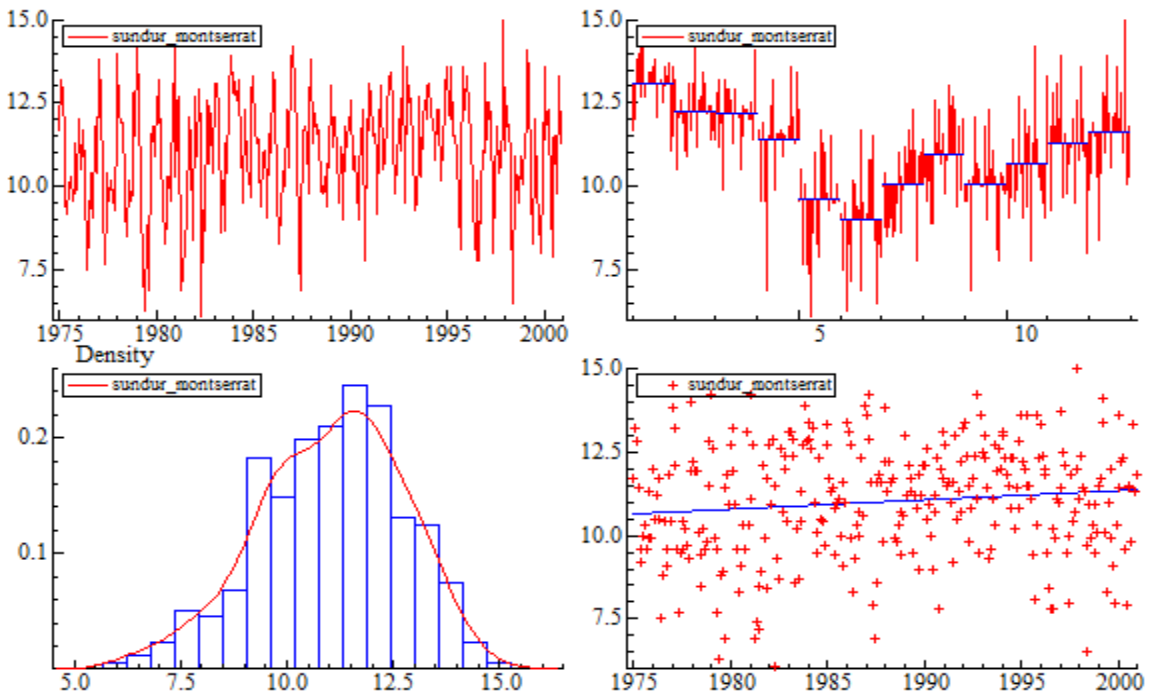
from the sea, adopting in-house energy systems, recycling. Similarly, Emmanuel and Spence (2009), estimates that in 1996 total water demand by hotels, ships and golf courses in Barbados was 2,569,000 cubic metres, approximately one sixth of total domestic water consumption in Barbados. It is projected that by 2016 total demand in the industry should rise to 5,573,000 and account for one third of total domestic usage. Such growth in water demand could place pressure on supply and result in shortages for both tourism-related establishments as well as residential consumers. Griffith (2001) notes that such shortages can lead to relatively negative perceptions of the tourist industry.

There is a growing body of literature aimed at evaluating the potential impact of climate change on Caribbean economies. GCSI (2002) provides an assessment of the economic impact on climate change on Caribbean Community (CARICOM) countries based on the assumption that no adaptation to climate change occurs. The estimates are very preliminary and numerous assumptions were made in the calculations. The study reports that the cost of the potential damage ranges from US\$1.4 to US\$9 billion. Most of the damage assessment is driven by loss of land, tourism infrastructure, housing, other buildings and infrastructure due to sea-level rise. Moore, Harewood and Grosvenor, (2010) using a micro-simulation approach, provide supply-side estimates of the impact of sea level rise and increased extreme events on Barbados. In the case of sea-level rise, the study estimates that loss of revenue from tourism could be negligible in the best-case scenario and US\$150 million in the worst-case scenario. The costs associated with extreme climatic events were significantly larger, with loss of revenue from tourism in the best-case scenario estimated at US\$355.7 million and as high as US\$2 billion in the worst case scenario. In relation to the demand-side costs of climate change (i.e. climate change shifting the tourism features of the Caribbean), Moore (2010) estimates the cost to the region of about US\$118 million to US\$146 million per year. The effects on three Caribbean islands, Bermuda, Jamaica and Trinidad and Tobago, were particularly severe with arrivals falling by around 5% per year due to the effects of climate change.

While a growing body of literature has emerged to look at the impacts of climate change on tourism in larger Caribbean islands, there is still a dearth of literature examining some of the emerging markets. This study, therefore, provides an assessment of the potential impact of climate change on the tourism sector in Montserrat. Similar to Moore (2010) and Moore, Harewood and Grosvenor (2010) both demand and supply-side estimates are provided. In contrast to these studies, however, an attempt is also made to look at the potential costs of mitigation and adaptation. The structure of the report is given as follows. After the introduction, Section 2 provides a review of the economic background for Montserrat as well as historical climate trends. Section 3 discusses the database employed in this study, while Section 4 outlines the empirical approach employed to model the impact of climate change on tourism on the two islands of interest. Section 5 provides an assessment of the potential costs associated with adaptation and mitigation. Section 6 concludes with policy recommendations.

II. BACKGROUND

Montserrat is a relatively small overseas territory of the United Kingdom (



Source: Data compiled by author

Table 15:

Details of cost-benefit scenarios). The island is located 43 km southwest of Antigua and 92 km northwest of Guadeloupe. At its longest point, Montserrat is 17.7 km long and as wide as 11.3 km, giving a total area of 102.6 sq. km. The highest point on the island is Chances Peak (915 m).

Figure 2: Map of Montserrat

Source: Gray (2010)

The eruption of the Soufrière Hills Volcano in 1995 has had a devastating effect on the island. Gray (2010) reports that 65% of the housing stock and 90% of commercial buildings were destroyed, including the capital Plymouth as well as the airport and seaports. The dislocation caused by the eruption resulted in the emigration of approximately 6,500 persons, or about 63% of the total population of the island. At present, therefore, Montserrat is divided into two zones: (a) a Safe Zone in the north (representing about one third of the island); and, (b) an Exclusion Zone in the south covering the remaining two thirds of the island.

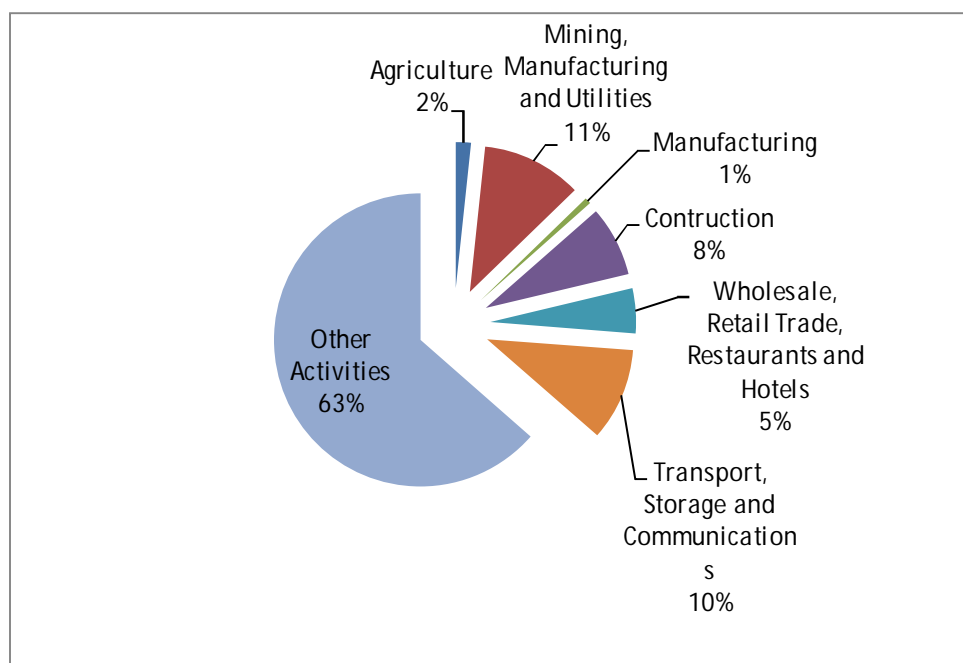
In spite of the devastation caused by the Soufrière Hills Volcano, the island still maintains 4 protected areas or about 30% of the Safe Zone. The protected areas include: the Centre Hills Forest Reserve; Piper's Pond Wildlife Reserve; Silver Hills Forest Reserve; and, Foxes Bay Bird Sanctuary (which has been severely affected by the eruption). Beukering et al. (2008) estimates, that the total economic value of the Centre Hills protected area is about US\$1.4 million per year, largely due to its importance as the main water source on the island. Part of the area's value was also related to its importance as a tourist attraction as well as the habitat for a number of species.

A. ECONOMIC REVIEW

Given the economic and social devastation caused by the eruption, Montserrat is highly dependent on United Kingdom government grants to finance government operations. The precipitous decline in the island's population has also had a perverse impact on per capita GDP. Indeed, the United Nations National Accounts Statistics Division estimates that per capita GDP for 2009 was US\$8,897 compared to an average of US\$6,665 for the rest of the region. While the statistics suggest that the island's standard of living has improved relative to regional standards, a more in-depth analysis of the figures would suggest that most of the increase was due to the decline in population.

In 2009, total real value-added of goods and services¹ produced in the island was estimated at US\$44.5 million compared to US\$99.5 million in 1990. Figure 3 suggests that most of this activity is due to general services, which accounts for 63% of total value-added. However, transport, storage and communications as well as construction were also major contributors to economic output as well. Wholesale, retail trade, restaurants and hotels have been particularly affected by the eruption. Prior to 1995, the industry was earning almost US\$10 million in value-added annually. During 2009, however, the group was responsible for just US\$2.3 million in value-added.

Figure 3: Breakdown of Real Value-Added in Montserrat (2009)



Source: United Nation's National Accounts Main Aggregates Database (unstats.un.org)

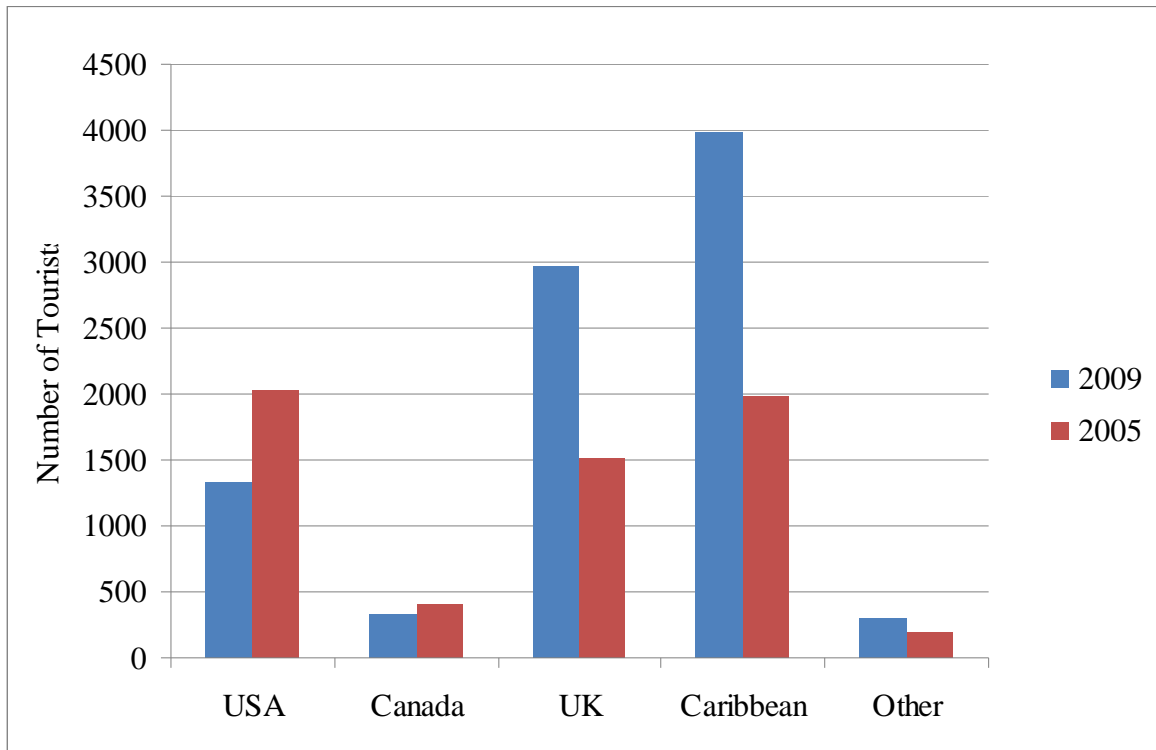
Nevertheless, the island has been able to revive its travel and leisure product, built primarily around nature tourism. Like most Caribbean countries, the tourism product in Montserrat is based around the sea. The island's beaches reflect the impact of past volcanic eruptions and, therefore, tend to be grey. In

¹Base year for real GDP is 2005.

addition, some are only available by boat or a hike. Diving and snorkelling are also becoming popular tourist activities, as the pyroclastic flows into the sea surrounding the island has added new substrates for reefs and protected the marine ecosystem from human activities. As most of the island lies in the Exclusion Zone, a number of hiking trails have developed so that visitors can explore the entire island. Of course, volcano viewing has also emerged as a popular tourist attraction.

Like most other Caribbean countries, Montserrat has been significantly affected by the global recession. In 2009, 7,875 tourists visited the island, down from 10,159 in 2008 and 10,450 in 2007 (ECCB, 2009). It is estimated that these tourists spent almost US\$5.2 million in 2009 (almost 23% of GDP), down from US\$7.1 million one-year prior and US\$9.1 million in 2005. As an indicator of the importance of the tourism industry, foreign-exchange earnings from tourism on the island were almost five times more than that from merchandise exports. The majority of tourists visiting the island are stay-over arrivals, with most of the remainder due to excursionists. Figure 4 suggests that the main source markets for stay-over visitors tend to be the rest of the Caribbean, the United Kingdom as well as the United States of America. However, arrivals from both the United Kingdom and the rest of the Caribbean have dropped significantly within the last five years, while those from the United States have continued to rise. Canada and other markets were relatively flat over the last five years.

Figure 4: Breakdown of stay-over visitor arrivals for Montserrat



Source: ECCB, 2009

The island's popularity as a cruise destination has grown in recent years. In 2008, the total number of cruise ship calls was estimated at 354, compared to 311 in 2007 and 269 in 2005. However, the effects of the global downturn have had a negative effect on the industry, with the number of cruise ship calls

falling to 299 in 2009. The number of yachts visiting the island has also contracted significantly in 2009, after registering significant growth during the 2005-2008 period. At the end of 2009, the total number of yachts visiting the island was estimated at 1353, down significantly from the 1840 reported for 2008, but still higher than the 1143 obtained in 2005.

B. TRANSPORTATION COSTS

The major source markets for Montserrat tend to be the United States, United Kingdom, Canada and the rest of the Caribbean. To provide an indication of the cost of travel faced by visitors to these islands, indicative travel fares from major cities in source markets are provided in table 2. For comparison purposes, indicative rates for Jamaica (a major travel destination in the Caribbean), are also provided.

In the case of Montserrat, the cost of travel for visitors from New York (US\$594) was more than 1.5 times higher than the fare paid by a visitor to Jamaica, while for Toronto the fares were more than 2.5 times higher than those faced by Canadian visitors going to Jamaica. In contrast, the fares for tourists coming from London were quite similar to that for Jamaica, while regional tourists coming from Barbados would have to pay about US\$70 more to visit Montserrat. Higher oil prices or green taxes implemented on travel from more developed States is, therefore likely, to have a significant demand on travel to the island, as relative prices are already quite high.

Table 2:
Indicative airfares for Montserrat from major cities

| | <i>As at August 10, 2010 (US\$)</i> |
|----------------------------|-------------------------------------|
| To Montserrat from: | |
| New York | 594* |
| London | 980* |
| Toronto | 1394* |
| Bridgetown | 468* |
| | |
| To Jamaica from: | |
| New York | 378 |
| London | 1126 |
| Toronto | 548 |
| Bridgetown | 398 |

Source: www.aa.com; www.britishairways.com; www.aircanada.com; www.liatairline.com; www.caribbean-airlines.com

*includes cost of return ferry to Antigua and Barbuda (US\$94).

C. REVIEW OF LITERATURE

1. Review of the economic effects of climate change on tourism

Much of the early research examining the likely effects of climate change on tourism zeroed in on one variable, namely temperature. One of the earliest studies in the area, Koenig and Abegg (1997), provided an assessment of the likely effects of changes in weather conditions on the winter tourist industry in Switzerland. The authors reported that, under current climate conditions, 85% of all Swiss ski areas are snow-reliable. However, this number would drop to 63% if temperatures were to rise by 2°C and therefore have implications for regionally balanced economic growth.

The initial research has since been followed by a larger number of studies, all using a similar approach (Beniston, 2003). This body of literature suggests that climate change is likely to: (a) lengthen the tourist season, and; (b) impact on the natural environment. Lise and Tol (2002), using temperature as their main measure of the effects of climate change, find that the optimal or preferred temperatures of visitors emanating from the Organisation for Economic Cooperation and Development (OECD) group of countries is around 21°C. The authors therefore suggest that global warming could result in a shift away from some destinations that deviate significantly from this ideal temperature.

One of the drawbacks of the approaches suggested above is that they focus on just one particular characteristic of a destination's weather (temperature) to make predictions of the likely impact of climate change. Scott and McBoyle (2001) therefore use a Tourism Climatic Index (TCI) to evaluate the potential impact that climate change can have on the tourist industry in 17 United States cities. The authors calculated historical as well as projected TCIs for two scenarios obtained from the Canadian Centre for Climate Modelling and Analysis Coupled Global Climate Model (CGCM2) and the United Kingdom's Meteorological Office Hadley Centre Coupled Model (HadCM2) for the 2050s and 2080s. The results suggested that western Canadian cities (Calgary, Vancouver, and Yellowknife) would experience some lengthening of the tourist season, while those in eastern Canada (Toronto and Montreal) should experience some deterioration. Harrison, Winterbottom, and Sheppard (1999) employed similar approaches in relation to the ski industry in Scotland, while Amelung, Nicholls and Viner (2007) used the simulated TCI approach to investigate the shifts that are likely to occur in tourist flows as a result of climate change in a sample of tourist destinations.

While simulating the TCI under various climate change scenarios provides important information on the relative attractiveness of a destination in the future, it cannot provide estimates of the impact these changes are likely to have on tourism demand. As a result, some authors have used the generated TCI in a model of tourism demand to project the potential impact of these forecasted changes on tourism features. Hein (2007), for example, augments a model of tourism demand in Spain with the TCI index for this country to identify the potential impact that changes in climatic conditions can have on the future of the industry. The author finds that tourist flows to this destination could fall by up to 20% by 2080 compared to 2004, largely due to higher temperatures during the summer. However, during the spring and autumn, there could be increased visitor arrivals.

One of the limitations of TCI approach is that it assumes there is some ideal climatic condition across destinations. Scott, Gossling and de Freitas (2007), however, argue that this might not necessarily be the case. The study examines tourists' perceptions of the ideal climatic conditions in relation to four variables (air temperature, precipitation, sunshine and wind) and in three regions (beach-coastal, urban and mountains). The study utilised responses to structured questionnaires from a sample of 831 university students from Canada, New Zealand and Sweden. The results suggested that the ideal climatic conditions

tended to vary in the three tourism environments. Moreover, the relative importance of the ideal climatic parameters was not the same across nations. While these results may suggest that the TCI may lead to some misleading preferences across countries, it was limited by focusing on a very small segment of the market, i.e. the young tourist.

2. Review of the impacts of El Niño and La Niña events

While the concept of climate change is the main focus of this report, the El Niño and La Niña events have been impacting on climate patterns in the Caribbean since formal reporting began. The El Niño and La Niña relate to ocean temperatures in the Equatorial Pacific that tends to have important implications for global weather conditions (see Figure 5). The El Niño event relates to a warming of the ocean temperatures in the region, while La Niña is abnormally cold ocean temperature. The most studied El Niño events in recent history were those in 1986-87, 1991-1992, 1993, 1994 and 1997-1998. The 1997-1998 El Niño event was particularly severe: the strongest in over 50 years of data gathering. During that period, the deviation of ocean temperatures in the Equatorial Pacific was about 4 degrees above normal. In contrast, the most recent La Niña events occurred in 1988 as well as 1995. It is possible that future greenhouse gas emissions might impact on the El Niño and La Niña phenomena. Collins (2000), using the Second Hadley Centre Coupled Model, finds that the El Niño (La Niña) would increase in amplitude should greenhouse gas emissions approach four times preindustrial values. However, Cane (2005), analysing the evolution of El Niño (La Niña) events over the last 130,000 years, notes that data from corals show substantial decadal and long variations in the strength of the phenomena cycle. Therefore, it is difficult to predict what would be the impact of higher greenhouse gas emissions. Timmermann et al. (1999) make a similar suggestion.

Figure 5:
The Equatorial Pacific Ocean



Source: Data compiled by author

El Niño has been shown to have far reaching impacts on global climate. Westra and Sharma, (2010) consider the upper bound of predictability of global precipitation at the seasonal time scale. The results suggest that total precipitation variance around the world is largely explained by the fluctuations in the El Niño phenomenon. to the 1830s there was a statistically significant relationship between fires in northeast Mexico and dry La Niña years (Yocom, et al., 2010). Since this era, however, both El Niño and La Niña episodes have been associated with dry years and thereby fires. These results seem to imply that the impact of the events tend to change over time. Xie et al. (2010) find that El Niño has had statistically significant influences on climate in the Indo-Western Pacific and East Asia. The phenomena's effects were particularly evident since the climate regime shift of the 1970s. This effect tends to be more indirect: via El Niño's impact on sea surface temperatures for the Indian Ocean. Within the Caribbean, Malmgren et al. (1998) reports that the Southern Oscillation Index (SOI) has controlled air temperatures in Puerto Rico since 1914, with El Niño years positively associated with higher temperatures and La Niña associated with cooler temperatures. Precipitation patterns, in contrast, were controlled by variations in the North Atlantic Oscillation (NAO).

Given the vulnerability of small islands to hurricane strikes, the potential impact of climatic changes on formation of naturally occurring phenomena is of particular importance. Chand et al. (2010) consider the impact of the El Niño (La Niña) phenomena on the formation of tropical cyclones affecting Fiji, Samoa and Tonga region. The results seem to suggest that in El Niño years, more cyclones are observed to form within the region affecting the three islands relative to the La Niña years. However, the number of storms forming outside the region, and then affecting the islands is greater during La Niña years. Using a Poisson regression model, Chand et al. consider the predictive ability of various factors as they relate to the formation of storms affecting the region. The results suggest that the El Niño phenomenon was an important predictor of the annual number of storms forming within the region. However, Wallace and Anderson (2010), using detailed records from ca. 5300-900 year. B.P, find no significant relationship between intense storm impacts across the north-western Gulf of Mexico coast and changing climate conditions. In contrast, Kossin et al. (2010) do find that the SOI is an important predictor of the formation of storms in the Northern Atlantic region. The study separates storm and hurricane tracks from 1950 to 2007 using four clusters. The authors report that tropical cluster members are influenced by the El Niño southern oscillation, as well as the Atlantic meridional mode and the Madden-Julian oscillation. Tartaglione et al. (2003) focus specifically on the relationship between hurricane landfalls and phases of El Niño (La Niña) events. The results suggest that cold phases (La Niña) tend to increase strike probabilities in the Caribbean relative to neutral or warm phases (El Niño). Similar results are reported by Landsea (1999).

El Niño and La Niña events can also have important biological implications. Magnusson et al. (2010) find that the population of a rodent species, *Necromys lasiurus* (Hairy-tailed Bolo Mouse), as well as rainfall and regional fires in the Amazonia savannah tend to be correlated with variations in the temperature of the SOI. The results suggest that the rodent population and fires were positively associated with the index, while rainfall was inversely associated with the SOI. A similar link for amphibians was also found by Rohr and Raffel (2010). The authors find that amphibian defences against pathogens tend to be highly correlated with regional temperature variability. The study attributes the decline in defences largely to the El Niño phenomenon. These results suggest that changes to temperature variability, associated with climate change, could lead to biodiversity damage and disease emergence. Black et al. (2010) also find that SOI also plays a significantly role in explaining fluctuations in populations of rockfish populations in California. Kaars et al. (2010), using data for the last 250 years, find a significant association between Dipterocarpaceae pollen, reflective of mass-flowering during El Niño drought events in Indonesia and elevated charcoal levels, and indicative of increased incidence of fires. With regards to human health, Zhan et al. (2010), find a statistically significant correlation between haemorrhagic fever with renal syndrome and the SOI in China. In addition to El Niño and La Niña, the authors also report that land surface temperature and relative humidity were also statistically significant explanatory factors.

The El Niño has also had significant effects on corals in the Caribbean. The most likely effect is coral bleaching, which occurs when colonies under physiological stress expel their symbiotic algae. This is usually done in response to high temperatures and solar radiation. Gill et al. (2006) note that elevated sea surface temperatures can be primary sources of stress for coral reefs; however, they can also be impacted by aerosol levels. The study finds that when aerosol levels are low, bleaching is influenced by the strength of the El Niño effect. However, relatively high aerosol levels (due to volcanic activity), can offset the effects of El Niño on coral reefs in the region. Gill et al. (2006) note, however, that aerosol levels are not a sustainable source of protection against future coral bleaching caused by the effects of El Niño. Aronson et al. (2000) provide an in-depth assessment of the impact of El Niño on corals surrounding Belize in 1998. The study reports that during that year sea temperatures around the barrier reef reached as high as 31.5 degrees centigrade at depths of 2m. and 10m. As a result, evidence of mass bleaching was therefore found in the fore-reef as well as lagoonal environments. Some colonies on the fore-reef experienced mortality, but most colonies recovered. In contrast, the impact on lagoonal areas was devastating. At two sites, all coral colonies were bleached white.

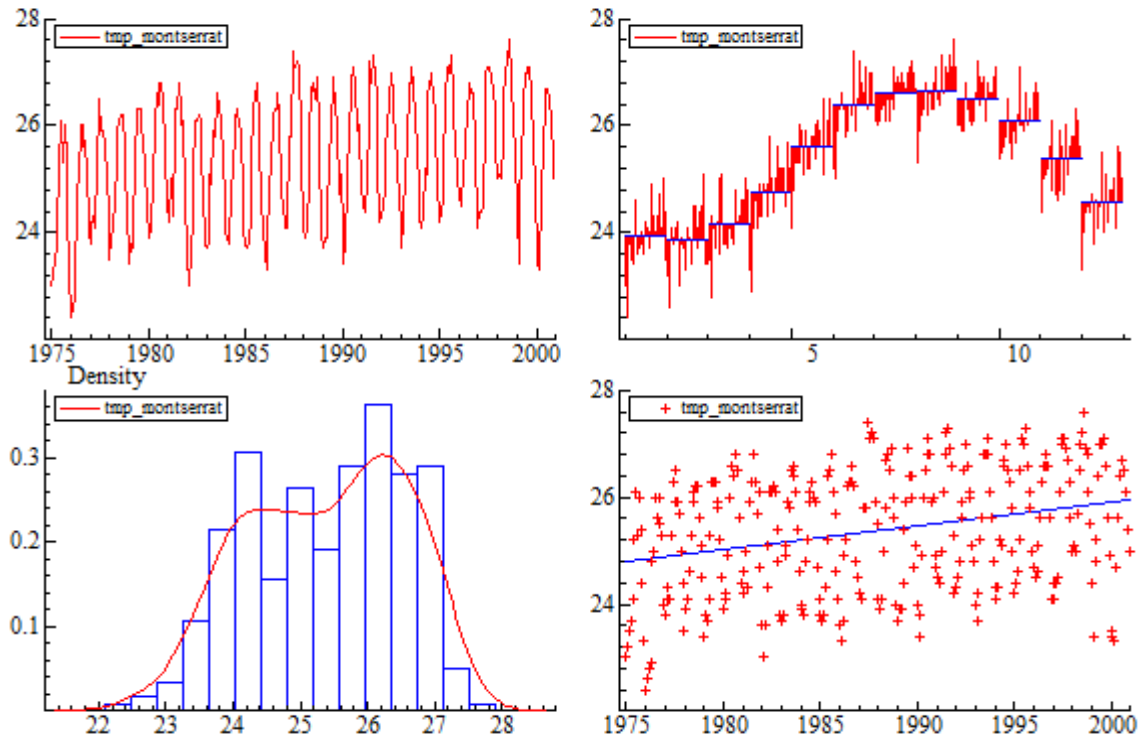
D. CLIMATIC PATTERNS²

Historical climate observations for Montserrat are obtained from Mitchell et al. (2004)³. As Figure 6 suggests, the mean temperature for the island usually fluctuated between 24°C to 27°C over the period. Examining the density plot as well, substantiated this. There is some seasonality in the temperature: the June-September period was usually about 2°C higher than the December to March period. There was some evidence of advancing average daily temperatures, with mean annual temperatures rising by about 0.8°C over the review period.

²There is a growing body of literature that looks at the impact of volcanic eruptions on global temperature variation, but this is beyond the scope of the current study.

³ Station data for this island did not provide the detail on the number of climatic features required for the study. It should be noted that the gridded observations provide an area-averaged picture. The observations were investigated to ensure that the standard deviation of the database was not driven by changes in the reporting station network. While the database provides observations from 1901, the start date used in this study is from 1975 to benefit from the greater precision of estimates in the latter period.

Figure 6:
Historical average daily temperature - Montserrat



Source: Data compiled by author

Average maximum daily temperatures tend to be at least 4°C higher than the average daily temperatures (27°C to 30.5°C). The density plot (see Annex) suggests that the majority of maximum daily temperature observations are above 30°C. In the June-September period maximum temperatures can reach as high as 31°C. The trend in the maximum temperature observations seems to imply that there are an increasing number of hot days and nights, with the average maximum monthly temperature rising by about 1°C over the review period.

In addition to temperature, relative humidity also plays a key role in human comfort. If relative humidity is high, then perspiration evaporates from the skin at a lower rate. Therefore, in two different environments where the temperature is the same, but the relative humidity is different, the area where relative humidity is higher tends to feel relatively warmer. Mieczkowski (1985) notes that in tourism destinations where average temperatures tend to be relatively high, air humidity can be even more important than the actual temperature as it relates to thermal comfort. To obtain data of relative humidity, observations on mean and saturated vapour pressure are employed. Mean vapour pressure are obtained from the climate database mentioned earlier. Saturated vapour pressure is estimated using the Goff Gratch equation. Relative humidity is then calculated as the ratio of mean and saturated vapour pressure (see Annex). During the traditional tourist season of December to April, relative humidity tends to be around 82%. These figures do seem to be falling slightly over the sample period.

Precipitation reduces the amount of time available for sightseeing and relaxing on the beaches in the Caribbean. If most of the precipitation in a given month is due to a few heavy showers, these might be relatively less of an inconvenience than persistently light showers. The ideal climatic indicator for

evaluating tourism comfort would therefore be the number of days with some minimal amount of precipitation. However these data were not available. Therefore the total monthly precipitation was employed instead under the assumption that more rainfall reduces the amount of time for traditional tourist activities. While less rainfall might be desirable for tourists, such trends can put pressure on local water resources and therefore limit the availability of some tourist activities (e.g. green golf courses, and swimming pools). Rainfall during the traditional tourist season tends to be comparatively low, particularly between January and March (see Annex). The database indicates that there was a slight reduction in average monthly precipitation during the period.

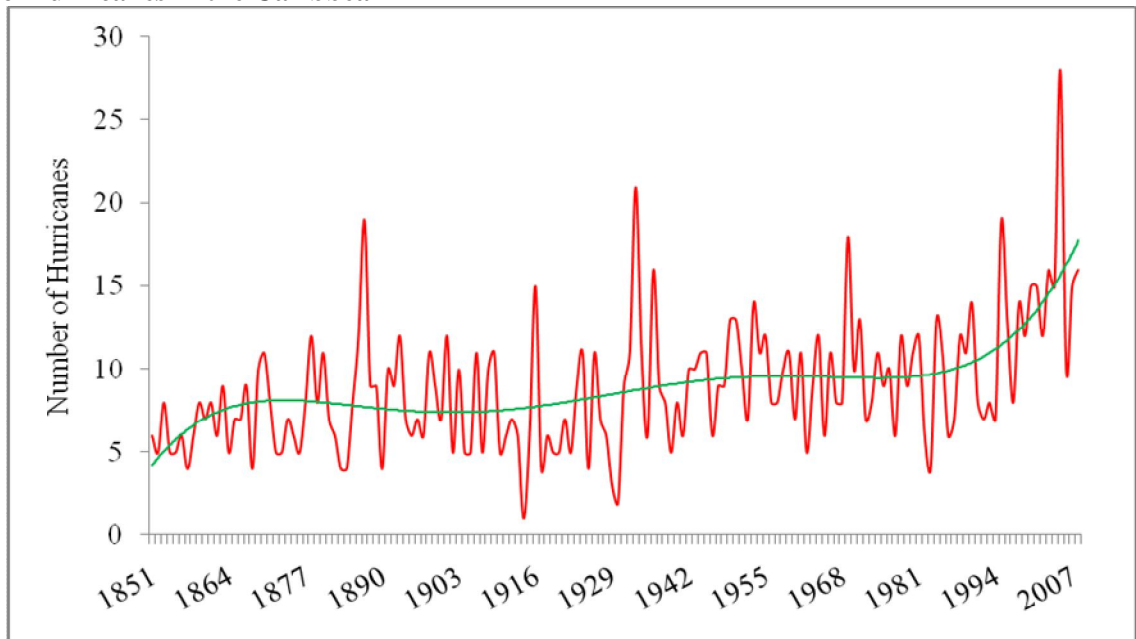
Closely related to precipitation is the number of hours of sunshine. Such conditions are needed for sunbathing, photography and other aspects of the Caribbean tourist experience. The percentage of possible total sunshine is estimated as the inverse of the degree of cloudiness. The possible total sunshine indicator has risen over the review period (see appendix). Similar to the other indicators, the seasonality of this indicator is quite conducive to tourism, with the possible total sunshine indicator highest during the traditional tourist season.

E. EXTREME EVENTS

Within the Caribbean, there has also been a rise in the number of hurricanes striking the region, not necessarily linked to the issue of climate change. Since the early twentieth century, the number of Atlantic hurricanes has risen from about 5-6 per year to more than 25 in some years of the twenty-first century (**Error! Reference source not found.**). There is no similar trend in the average intensity of these storms: on average, wind speeds for these storms tend to be 80 and 100 miles per hour (Figure 7). There was only one outlier year in the early 20th century when the average speeds for storms were 130 mph due to a storm with winds of more than 150 mph passing through the region.

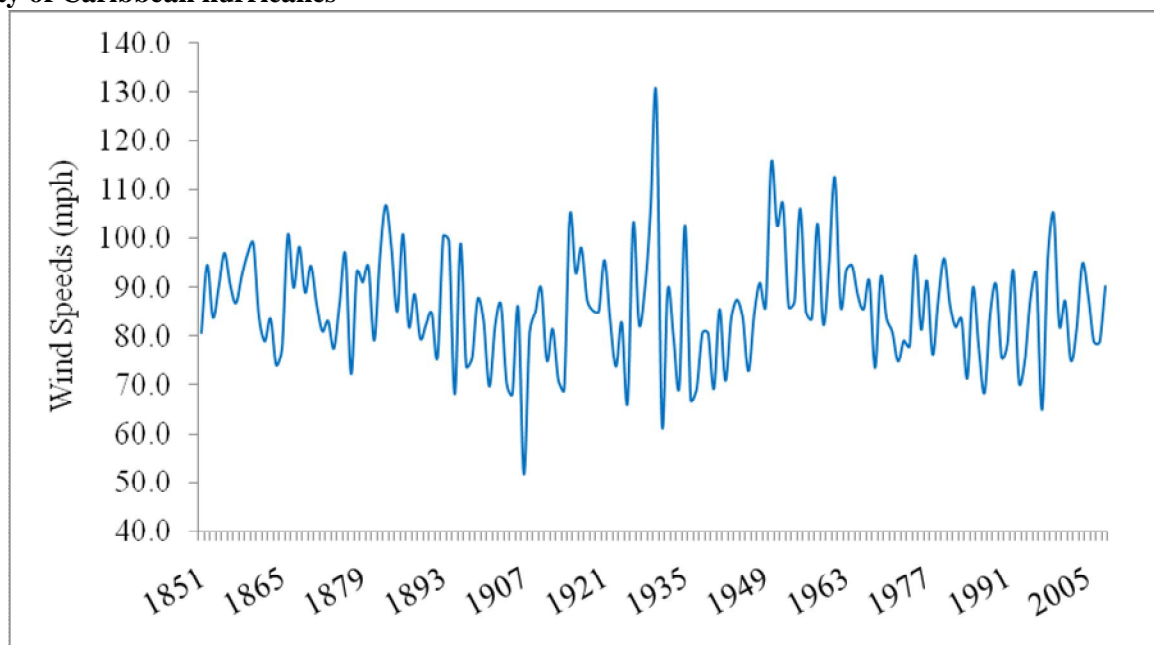
Figure 7

History of hurricanes in the Caribbean



Source: Tropical Prediction Centre: <http://www.aoml.noaa.gov/hrd/index.html>

Figure 7:
Intensity of Caribbean hurricanes



Source: Tropical Prediction Centre

Since 1979, Montserrat has been affected by five major storms causing extensive damage to the island: David (1979), Hugo (1989), Luis (1995), Georges (1998) and Lenny (1999). Table 3 provides the average damage caused by these storms. In the case of Montserrat, there were four storm events where 11 persons were killed and 12,040 persons affected. The estimated damage associated with these storms was US\$260 million or about five times GDP in 2009. On a per storm basis the damage estimate still exceeded annual output in the island: 123% of GDP. Due to the uncertain link between climate change and hurricane activity, no attempt is made in this study to forecast future storm activity.

Table 3:
Extreme events in Montserrat

| Event | Number of Events | Number Killed | Total Affected | Economic Damage (US\$mil) |
|-------------------|------------------|---------------|----------------|---------------------------|
| <i>Montserrat</i> | | | | |
| Hurricane/Storm | 4 | 11 | 12,040 | 260 |
| Average per event | | 3 | 3,010 | 65 |

Source: EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium)

F. BEACHES AND CORAL REEFS

The Ministry of Environment usually monitors beaches on Montserrat. Between 1990 and 1996 most of the beaches monitored showed erosion of between 1 and 3 meters. The island is particularly vulnerable to climate change (e.g. sea level rise and flooding) as the island's lowest point reaches zero feet at the

Caribbean Sea and 914m at the highest point. In addition, the majority of persons live in areas near the flatter coastal regions and are more likely to be affected by coastal inundation, inland flooding, greater storm surge damage and increased erosion.

Corals around Montserrat are found primarily as a series of scattered patch reefs ranging in depth from 2 m to 40 m. Reefs are most abundant off the west and north coasts, with additional reefs on the northeast and southeast. Gray (2010) reports, that in 1995 the island had identified 37 true coral species, 3 sea grass species, 37 algal species and 67 fish species. All of the island's reefs are under threat from human activities. The islands reefs are a key habitat for fisheries, and therefore play a key role in addressing issues related to food security, providing employment to fisher folk as well as an attraction to visitors. Reefs are also a natural coastal defence against the effects of erosion and storm damage and thereby allow the formation of mangroves and lagoonal areas, which are habitats for sea grass and mangroves.

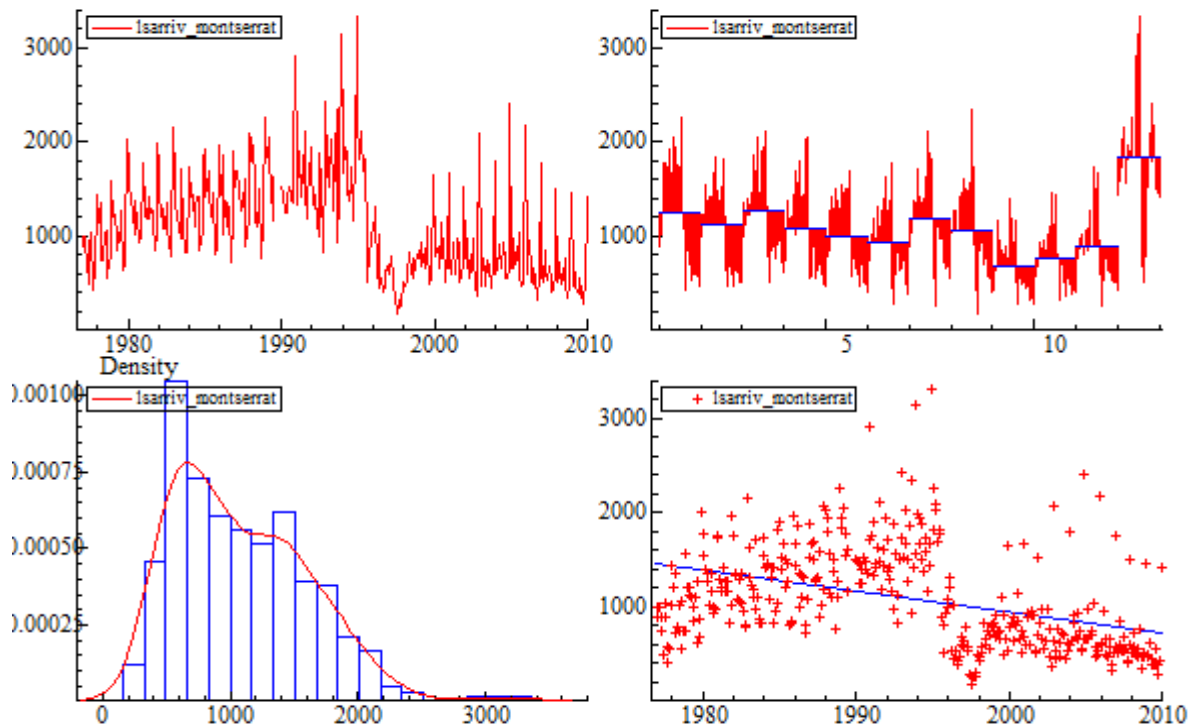
In addition to destroying the capital city of Plymouth, the 1995 volcanic events have also had significant effects on the reefs around Montserrat. The large plumes of sediment that entered the sea at several locations impacted on reefs primarily on the south and east of the island. Direct deposits of ash and waterborne sediment have resulted in coral bleaching and an increase in coral diseases. The reefs are also a nesting area for Green, Hawksbill and Leatherback turtles.

III. DATA COLLECTION AND ANALYSIS

A. TOURIST ARRIVALS

Observations on long-stay tourist arrivals are obtained from the Caribbean Tourism Organisation (CTO, Various Issues). For Montserrat the monthly series are available from 1977-2009. Figure 8 provides statistical plots for the observations. There is a clear structural break in the database in 1995 due to events associated with the volcanic eruption. Similar to most Caribbean countries, the largest number of tourist arrivals occurs in December. However, there is no clear difference in the other months. Figure 8 also shows that there is a downward trend in arrivals to the island, with average monthly arrivals falling from about 1500 to less than 1000.

Figure 8:
Long-Stay Tourist Arrivals in Montserrat



Source: Data compiled by author

B. CLIMATE CHANGE AND TOURISM FEATURES

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 TCI that was a weighted average of seven climatic variables: (a) monthly means for maximum daily temperature; (b) mean daily temperature; (c) minimum daily relative humidity; (d) mean daily relative humidity; (e) total precipitation; (f) total hours

of sunshine and; (g) average wind speed.⁴. Table 4 provides the weights and influence of each of variables used in the calculation of the index.

Table 4:

Components of the Tourism Climate Index

| <i>Sub-Index</i> | <i>Variables</i> | <i>Influence on TCI</i> | <i>Weight</i> |
|-----------------------------|---|--|---------------|
| Daytime Comfort Index (CID) | Maximum daily temperature; Minimum daily relative humidity | Represents thermal comfort when maximum tourist activity occurs | 40% |
| Daily Comfort Index (CIA) | Mean daily temperature; Mean daily relative humidity | Represents thermal comfort over the full 24 hour period, including sleeping hours | 10% |
| Precipitation (P) | Total precipitation | Reflects the negative impact that this element has on outdoor activities and holiday enjoyment | 20% |
| Sunshine (S) | Total hours of sunshine | 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% |

Source: Data compiled by author

The calculated TCI ranged from -20 (impossible) to 100 (ideal), with further descriptive rating categories provided in Table 5. 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 5:

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 |

Source: Data compiled by author

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 employed the approach outlined by

⁴ Each variable was standardised to take values ranging from 5 for optimal to -3 for extremely unfavourable before the index was calculated.

Mieczkowski (1985) to calculate the TCI for 289 countries. Following Mieczkowski, the TCI is calculated as follows:

$$TCI = 2[(4 \times CID) + CIA + (2 \times P) + (2 \times S) + W] \quad (1)$$

The database provides projections from four models:

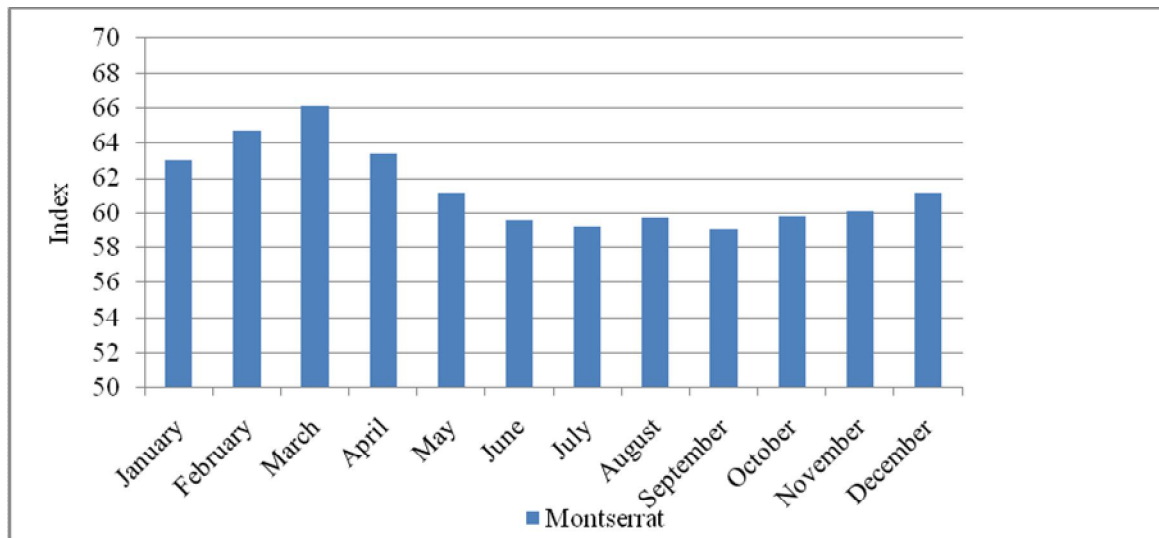
- (a) The Canadian Centre for Climate Modelling and Analysis Coupled Global Climate Model, CGCM2;
- (b) Australia's Commonwealth Scientific and Industrial Research Organisation, CSIRO2;
- (c) Parallel Climate Model, PCM; and,
- (d) The UK Meteorological Office Hadley Centre Coupled Model (HADCM3).

Two emissions scenarios (A2 and B2) outlined by the Intergovernmental Panel on Climate Change (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 B2 scenario uses the long-term United Nations Medium 1998 population projection of 10.4 billion by 2100 and makes the assumption of some reduction in greenhouse gas emissions, while the A2 scenario assumes a high population growth of 15 billion by 2100, owing to a significant decline in mortality for most regions, and little or no change in greenhouse gas emissions. 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 two emission scenarios provide eight combinations of climate model and emission scenarios (A2 and B2). These forecasted climate indicators are used to calculate anticipated change in the TCI for Montserrat.

The results for the historical TCI (Figure 9) confirm that the best time to visit Montserrat 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. The historical analysis of tourism climatic features in Montserrat matches fairly closely with the traditional tourist season in the Caribbean. Between December and April, the region usually receives more than 60% 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 visitors emanate from these regions.

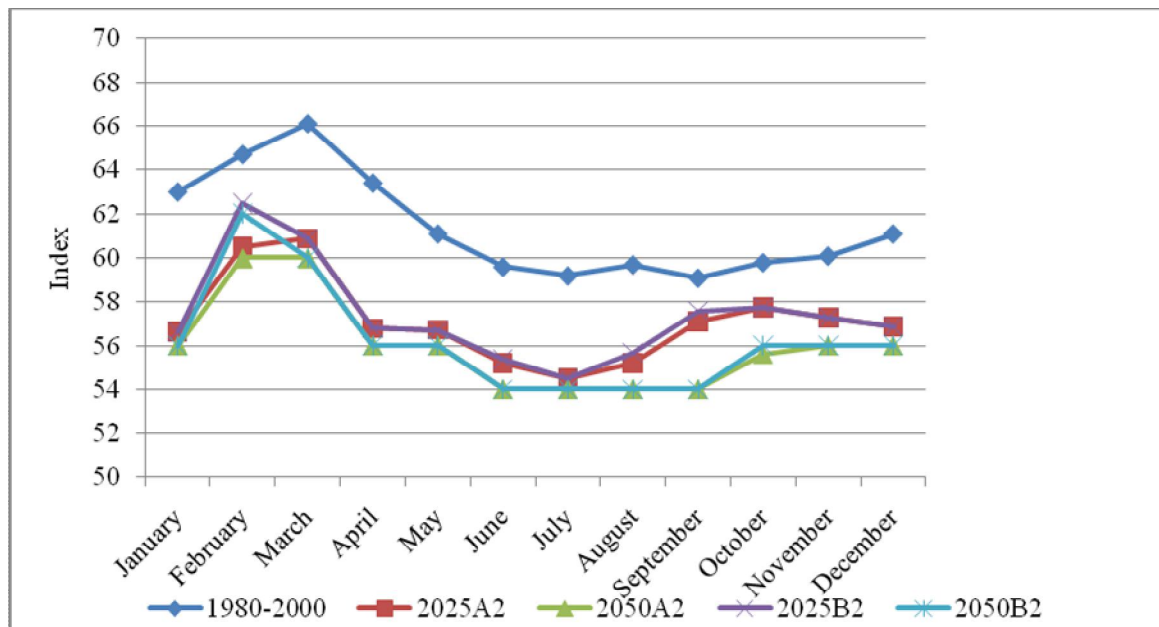
Figure 9:
Historical TCI for Montserrat (1980-2009)



Source: Data compiled by author

Using the projected climate data, the TCI for the island is simulated for 2025 and 2050. The results are provided in Figure 10. The figure suggests a clear downward shift in the TCI for the island, indicative of deterioration in its suitability for tourist activities. During the traditional tourist season the index declines from the region usually classified as “good” to the “acceptable” region.

Figure 10:
Projected TCI for Montserrat in 2025 and 2050



Source: Data compiled by author

IV. QUANTIFYING THE IMPACT OF CLIMATE CHANGE ON TOURISM

A. TRAVEL DEMAND

The TCI offers a useful way to summarise the potential implications that climate change could have on the attractiveness of a destination. However, it does not present a quantitative assessment of the prospective impact on tourism demand. To obtain such an estimate, a standard demand model is augmented with the TCIs for Montserrat.

Following Harvey (1989), a general structural time series (STS) model is employed to model tourist arrivals to Montserrat. The model can be expressed as:

$$\begin{aligned} y_t &= \mu_t + \phi_t + \sum_{i=1}^k \sum_{\tau=0}^q \Delta_{i\tau} x_{i,t-\tau} + \sum_{j=1}^h \lambda_j w_{j,t} + \varepsilon_t \\ \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t \\ \beta_t &= \beta_{t-1} + \xi_t \end{aligned} \quad (2)$$

where μ_t is the trend in tourist arrivals, ϕ_t is the cyclical component, x_{it} is an exogenous variable, w_{jt} is an intervention (dummy) variable, $\Delta_{i\tau}$ as well as λ_j are unknown parameters and ε_t is the irregular component, which are all assumed to be stochastic. The parameter β_t is the slope of the trend component, with the stochastic properties of the level and slope driven by η_t as well as ξ_t . The cyclical component in trigonometric form may be expressed as follows:

$$\phi_t = \sum_{j=1}^{\frac{s}{2}} \phi_{jt} \quad (3)$$

with ϕ_{jt} determined by:

$$\begin{bmatrix} \phi_{jt} \\ \phi_{jt}^* \end{bmatrix} = \rho \begin{bmatrix} \cos \lambda_j & \sin \lambda_j \\ -\sin \lambda_j & \cos \lambda_j \end{bmatrix} \begin{bmatrix} \phi_{j,t-1} \\ \phi_{j,t-1}^* \end{bmatrix} + \begin{bmatrix} \omega_{jt} \\ \omega_{jt}^* \end{bmatrix} \quad (4)$$

where $\lambda_j = \frac{2\pi j}{s}$ is the frequency in radians and ρ is the damping factor ($0 < \rho \leq 1$). Traditional econometric models assume that the trend, seasonal and irregular components are stable. However, this is not likely to be the case, particularly over long periods of time. If these components are not stable then traditional econometric model formulations would be inadequate and the structural times series formulation preferred as it allows these regression coefficients to change over time (Harvey, 1989).

A priori, two explanatory variables are employed in the regression: real GDP and the TCI. The TCI is anticipated to be positively associated with tourist arrivals indicating that an improvement in tourism features results in a rise in tourism demand. To obtain projections of tourism up to 2050, forecasts of the TCI, discussed earlier, under the A2 and B2 scenarios are employed. Forecasts for US real GDP under the B2 scenario are derived from a univariate STS model, while the A2 scenario assumes that growth is moderated by about 2% per year. All models are estimated using STAMP 8.2 (Koopman, Harvey, Doornik, & Shephard, 2009). The estimation algorithm chooses optimal lag lengths. To obtain forecasts of visitor expenditure, tourist arrivals are multiplied by average visitor expenditure for long-stay passengers of US\$777 obtained from the CTO⁵.

⁵ [http:// www.onecaribbean.com](http://www.onecaribbean.com)

B. SPECIES, ECOSYSTEMS AND LANDSCAPES

Species, ecosystems and landscapes are a key part of the tourism product in Montserrat. Coral reefs, in particular, provide ecosystem services that are, in general, vital to tourism and society. The present concentration of carbon dioxide in the Earth's atmosphere is above 380 ppm (Hoegh-Guldberg O. e., 2007; Hoegh-Guldberg, et al., 2007). Should this reach 560 ppm, decreases in coral calcification and growth by 40% are likely, principally due to the inhibition of aragonite formation as carbonate-ion concentrations fall. Hoegh-Guldberg et al. (2007) also notes that while changes in ocean acidity will vary from one region to the next, the Caribbean Sea could approach risky levels of aragonite saturation more rapidly. Three scenarios are provided: (a) CRS-A, carbon emissions are stabilised at current levels; (b) CRS-B, assuming that the growth in carbon emissions remains at its current level and therefore the level of carbon dioxide in the atmosphere reaches 450 to 500 ppm, and; (c) CRS-C, increases in carbon dioxide emissions to >500 ppm. Under CRS-A, coral reefs will continue to change but should still remain coral dominated and carbonate accreting. With CRS-B the diversity of coral reefs decline along with a fall in habitat complexity and the loss of biodiversity, while with the CRS-C scenario coral reef ecosystems could be reduced to crumbling frameworks with few calcareous corals.

Unfortunately, there are no estimates of the economic impact of coral reefs in Montserrat. Burke et al. (2008), however, estimates the direct economic impacts from visitor expenditure as it relates to coral reefs of around US\$91.6 million in Saint Lucia or about US\$540 per person. Indirect impacts due to support services for tourism contributed an additional US\$68-US\$102 million, or US\$400 per person. It is assumed that similar per capita impact estimates hold in Montserrat. The negative impact of climate change on coral reefs in the region under the various climate change scenarios are obtained using the following formula: $CL = E(\text{Coral Loss}) * \text{Value of Coral Reefs}$. Due to uncertainty, as it relates to coral loss estimates three values are used: A2 (80%), B2 (40%) and BAU (10%). The values of coral reefs in Saint Lucia used in this study are those provided by Burke et al. (2008).

C. LAND LOSS

Tol (2002) divides the costs of sea level rise into three components: (a) cost of protective constructions; (b) cost of foregone dry land services; and (c) costs of foregone wetland loss services. For Latin America and the Caribbean, Tol estimates that a one-metre sea level rise would result in a total cost of US\$2 billion per year for the region. Estimates were obtained by combining information on coast length and various assumptions regarding key policy variables.

This study uses the estimates derived by Simpson et al (2010) in order to quantify the magnitude of damage resulting from the impacts of climate change. The major impacts of sea level rise are considered to be coastal inundation and inland flooding, damage due to storm surges as well as coastal erosion that are likely to significantly impact on coastal infrastructure, ecosystems as well as heritage resources. Simpson et al (2010) provides estimates of the impact of sea level rise on land area, people, ecosystems, economic value, important infrastructure as well as cultural heritage. Using a Geographic Information System the effects of inundation from sea level rise in each CARICOM State is obtained under the 1m and 2m scenarios. The study also provides vulnerability estimates of the combined flooding risk of sea level rise and storm surge for a 1 in 100 year storm (averaged for each country).

Related to these geospatial impacts, Simpson et al (2010) also provide estimates of the economic cost of climate change: annual costs and capital costs. The annual costs are the recurrent costs or damage to the economy from sea level rise, while the capital costs approximate the costs to the State from rebuilding or relocating assets as well as lost land value. These impacts are developed from the micro (e.g. damage to port, individual properties), meso (e.g. sector, city or region) and macro-level (e.g. State level). Results are

available for the high sea level rise scenario as well as the mid-range sea level rise scenario. These damage estimates differentiate between damage done to wetland, dry land, residential property, tourist resorts, infrastructure, seaports and airports, power plants, tourist expenditure loss, agriculture loss, industry loss and impacts of erosion.

D. DISCOUNT RATE AND BUSINESS AS USUAL SCENARIO

Given the long-run nature of climate change impact assessments, it is quite common to calculate the present value of the impacts calculated over the 50- or 100-year horizon. There is, however, no commonly accepted notion of what discount rate should be used. Zhuang, Liang, Lin and De Guzman (2007) note that social discount rates vary from between 3%-7% in developed countries to 8%-15% in developing states. This divergence reflects the differences in “economic structure, capital scarcity, stage of financial development, efficiency of financial intermediation, impediments faced in accessing the international capital market and social time preference”. As a result, this study adopts a somewhat eclectic approach by using a number of discount rates: 1, 2 and 4. All calculations begin from 2008.

Results in the study are also compared relative to a so-called business as usual scenario (BAU). BAU in this study is interpreted to mean the likely future scenarios for key economic and environmental variables in the absence of changes in climatic patterns. In the case of tourism therefore, the BAU scenario is derived by assuming that tourist arrivals continue to grow at historical trend growth rates. For coral reefs, the business as usual scenario assumes that even without climate change, human activity will have future effects on coral reefs in the region. As a result, the business as usual scenario is therefore based on Hoegh-Guldberg et al. (2007) and assumes that 10% of coral reefs are lost by 2050. In relation to land loss, the BAU scenario assumes that no land loss takes place.

V. ECONOMETRIC RESULTS AND SIMULATIONS

The econometric results attained by estimating Equation (3) are provided in table 6. The estimated model is able to explain 66% of the variation in tourist arrivals. The income elasticity of demand is positive and greater than one, indicating that a 1% rise in income in United States is likely to have a more than 1% impact on demand for the two countries under investigation. With regards to the TCI, the elasticity was also positive suggesting that an improvement in tourism conditions has a positive and statistically significant impact on demand.

Given that the main purpose of the model is to provide forecasts of tourism conditions, out-of-sample predictive tests were conducted on the estimated models. Two statistics are computed: (a) a predictive failure test (pft), and; (b) a CUSUM t-tested. The test statistic for the predictive failure test is:

$$pft = \sum_{j=1}^L v_{T+j}^2 \quad (4)$$

where v_{T+j} are the standardised residuals. . The statistic provides an evaluation of whether or not the forecast errors are statistically different from zero (if the errors are different from zero, this implies that the model produces biased forecasts). The statistic has a chi-square distribution with L degrees of freedom. The CUSUM t-test is computed from:

$$cusumt = L^{-\frac{1}{2}} \sum_{j=1}^L v_{T+j} \quad (5)$$

which is approximately distributed as a t distribution with $T - L - d^*$ degrees of freedom and evaluates whether or not the forecast errors fall within acceptable error bands. The statistics indicated that the residuals were neither biased nor statistically different from zero. These results therefore suggest that the models seem to provide relatively accurate out-of-sample predictions for the series under consideration.

Table 6:
Long-Run Regression Estimates

| Variable | Coefficient Estimates |
|---------------------|-----------------------|
| Ln(US GDP) | 1.081 (0.248)** |
| Ln(TCI) | 0.688 (0.248)** |
| | |
| Adj. R ² | 0.662 |
| Obs. | 288 |
| Failure Chi-squared | 21.196 [0.569] |
| Cusum t | 0.718 [0.480] |

Source: Data compiled by author

Notes: (1) Root mean squared errors are provided in brackets below coefficients.
(2) ** and * indicates significance at the 1 and 5% level of testing.

Using the STS model estimates provided in Table 6, forecasts of the change in tourist arrivals likely due to climate change are provided in

Table 7. The cumulative forecasted arrivals under A2 and B2 scenario are 718,325 and 735,647 tourists compared to 726986 in the BAU scenario. Based on a discount rate of 1%, the projected earnings of the industry over the 40-year horizon under the BAU scenario are US\$755.6 million. Under the A2 scenario, however, the earnings from the industry fall to US\$679.1 million, a loss of 145% of 2009 GDP.

Table 7:
Forecasted arrivals under various climate change scenarios

| | | | |
|---|-----------|-----------|------------|
| <i>Arrivals</i> | <i>A2</i> | <i>B2</i> | <i>BAU</i> |
| 2008-2020 | 118116 | 120946 | 127753 |
| 2021-2030 | 146921 | 150516 | 161818 |
| 2031-2040 | 194872 | 199530 | 217470 |
| 2041-2050 | 258416 | 264655 | 292262 |
| Total | 718325 | 735647 | 799303 |
| | | | |
| <i>Earnings(US\$ million)</i> | <i>A2</i> | <i>B2</i> | <i>BAU</i> |
| 2008-2020 | 123.34 | 126.29 | 133.40 |
| 2021-2030 | 153.42 | 157.17 | 168.97 |
| 2031-2040 | 203.49 | 208.35 | 227.09 |
| 2041-2050 | 269.84 | 276.36 | 305.19 |
| Total | 750.09 | 768.18 | 834.65 |
| | | | |
| <i>Present Value of Earnings (1% Discount Rate; US\$ million)</i> | <i>A2</i> | <i>B2</i> | <i>BAU</i> |
| 2008-2020 | 111.66 | 114.33 | 120.77 |
| 2021-2030 | 138.89 | 142.29 | 152.97 |
| 2031-2040 | 184.22 | 188.62 | 205.58 |
| 2041-2050 | 244.29 | 250.18 | 276.28 |
| Total | 679.05 | 695.42 | 755.60 |
| | | | |
| <i>Present Value of Earnings (2% Discount Rate; US\$ million)</i> | <i>A2</i> | <i>B2</i> | <i>BAU</i> |
| 2008-2020 | 101.18 | 103.61 | 109.44 |
| 2021-2030 | 125.86 | 128.94 | 138.62 |
| 2031-2040 | 166.93 | 170.92 | 186.29 |
| 2041-2050 | 221.37 | 226.71 | 250.36 |
| Total | 615.34 | 630.18 | 684.70 |
| | | | |
| <i>Present Value of Earnings (4% Discount Rate; US\$ million)</i> | <i>A2</i> | <i>B2</i> | <i>BAU</i> |
| 2008-2020 | 83.32 | 85.32 | 90.12 |
| 2021-2030 | 103.64 | 106.18 | 114.15 |
| 2031-2040 | 137.47 | 140.76 | 153.41 |
| 2041-2050 | 182.30 | 186.70 | 206.17 |
| Total | 506.74 | 518.95 | 563.86 |

Source: Data compiled by author

Coral reefs are one of the most important components of the regional tourism product. However, Hoegh-Guldberg et al. (2007) note that climate change could have potentially large and important effects on coral reefs in the region. The results for the effect of climate change on coral reefs under the A2, B2 and BAU scenarios are provided in Table 8. Using a discount rate of 1%, the value of coral reefs affected by 2050 is likely to be US\$403 million (7.6 times GDP in 2009) under the A2 scenario and US\$202 million (3.8 times GDP in 2009).

Table 8:
Value of coral reef affected

| | Value (US\$ mil) | | |
|----------------------------------|------------------|-----|-----|
| | A2 | B2 | BAU |
| Nominal | 600 | 300 | 75 |
| Present Value (1% discount rate) | 403 | 202 | 34 |
| Present Value (2% discount rate) | 272 | 136 | 16 |
| Present Value (4% discount rate) | 125 | 63 | 50 |

Source: Author's estimates.

The coastline in tourism destinations is a major part of the product. Beachfront properties often sell for more than those further inland. In addition, most major aspects of the economy also tend to be located along the coastline (e.g. government offices, electricity generation plants, etc.). The impact of a 1m (B2) and 2m (A2) rise in sea levels are provided in Table 9. For Montserrat, about 1% of the land area is lost under both scenarios. Simpson et al. (2010) therefore forecast that the impact on major tourism resorts is minimal. In all three scenarios, however, all the major ports are affected, both in the 1m and 2m sea level rise scenarios.

Table 9:
Impacts of Sea Level Rise on Infrastructure

| | Land Area | Population | Urban Area | Wetland Area | Agricultural Land | Crops and Plantation | Major Tourism Resorts | Airports | Road Network | Protected Areas | Sea Turtle Nests | Power Plants | Ports |
|---|-----------|------------|------------|--------------|-------------------|----------------------|-----------------------|----------|--------------|-----------------|------------------|--------------|-------|
| 1m Sea Level Rise | 1% | 1% | n.a. | n.a. | 2% | 1% | 0% | 0% | 4% | n.a. | 4% | 0% | 100% |
| 2m Sea Level Rise | 1% | 1% | n.a. | n.a. | 3% | 1% | 0% | 0% | 4% | n.a. | 8% | 0% | 100% |
| 1m Sea Level Rise and 1 in 100 year Storm Surge | 3% | 3% | n.a. | n.a. | 9% | 2% | 0% | 0% | 5% | n.a. | n.a. | n.a. | n.a. |

Source: Simpson et al. (2010)

Note: n.a. indicates not available.

The estimated annual and capital costs of this damage are provided in Table 10. Due to limited information, no annual cost estimates are available, only capital costs. In the mid range sea level rise scenario, the capital cost was estimated US\$20 million (38% of GDP), and US\$37 million (70% of GDP) in the high range scenario.

Table 10:
Annual and capital costs of sea level rise

| | | Annual Costs (US\$mil) | | | | Capital Costs (US\$mil) | | | | | | | | |
|---------------------------|----------------|------------------------|-------------|----------|--------------|-------------------------|-------|-------|--------------|----------|-----------------|---------------|--------------|-------|
| | GDP (US \$mil) | Tourism | Agriculture | Industry | Total Annual | Airports | Ports | Roads | Power Plants | Property | Tourist Resorts | Dry land loss | Wetland loss | Total |
| Mid range sea level rise | 111 | n.a. | 0 | 0 | 0 | n.a. | 17 | 0 | - | 0 | n.a. | 3 | - | 20 |
| High range sea level rise | 125 | n.a. | 0 | 0 | 0 | n.a. | 30 | 0 | - | 1 | n.a. | 5 | - | 37 |

Source: Simpson et al. (2010)

Note: n.a. indicates not available.

The estimated value of land loss in Montserrat is provided in Table 11. Using a discount rate of 1%, the present value of land loss was estimated at US\$25million (47% of GDP) under the A2 scenario and US\$13.4 million (25% of GDP) for the B2 scenario.

Table 11:
Estimated Value of Land Loss Due to Sea Level Rise

| | A2 | B2 |
|---|------|------|
| Land Area (km) | 102 | 102 |
| Expected Land Loss (km) | 1.02 | 1.02 |
| Nominal Value of Land Loss (US\$ mil) | 37.0 | 20.0 |
| Present Value of Land Loss (US\$ mil); 1% discount rate | 24.9 | 13.4 |
| Present Value of Land Loss (US\$ mil); 2% discount rate | 16.8 | 9.06 |
| Present Value of Land Loss (US\$ mil); 4% discount rate | 7.71 | 4.17 |

Source: Data compiled by Author

Given the above estimates, the total cost of climate change to the tourism product in Montserrat (using a discount rate of 1%) was estimated at US\$504.6 million under the A2, or 9.6 times the value of 2009 GDP and US\$208 million for the B2 scenario, or 5.2 times the value of 2009 GDP (Table 12). Given the significant effects likely to arise due to climate change, adaptation to climate change must be viewed not just as a means of insurance but also as an imperative to ensure the viability of Caribbean economies.

Table 12:

Total Estimated Impact of Climate Change on Tourism (US\$ Mil)

| Estimated Damage | 1% discount rate | | 2% discount rate | | 4% discount rate | |
|------------------|------------------|----------|------------------|----------|------------------|----------|
| | A2 | B2 | A2 | B2 | A2 | B2 |
| Tourism | (76.55) | (60.18) | (69.37) | (54.53) | (57.12) | (44.91) |
| Coral Reefs | (403.21) | (201.60) | (271.88) | (135.94) | (125.04) | (62.52) |
| Land | (24.85) | (13.43) | (16.76) | (9.06) | (7.71) | (4.17) |
| Total | (504.61) | (275.21) | (358.00) | (199.53) | (189.87) | (111.59) |

Source: Data compiled by author

VI. COST- BENEFIT ASSESSMENT OF ADAPTATION⁶ OPTIONS

A. CURRENT ATTEMPTS AT ADAPTATION

Montserrat has already begun to look seriously at potential adaptation options. As an overseas territory of the United Kingdom, however, the island is not party to either the UNFCCC or the Kyoto Protocol. Nevertheless, since 2005 the Department of the Environment, along with the Montserrat Tourist Board, Montserrat National Trust, Royal Botanic Gardens Kew, Durrell Wildlife and the Royal Society for the Protection of Birds have implemented a Darwin project to conserve the Centre Hills area. This process involved biological and socioeconomic assessments (e.g. management plans, outreach, increased local capacity for environmental management and the preparation of new environmental legislation to enable the Centre Hills to be designated a national park.

In addition, the government of Montserrat is also coordinating a project to establish the Organisation of Eastern Caribbean States (OECS) Climate Change Centre at the summit of the Silver Hills in the northern section of the island. The main goal of the Centre would be to identify and recommend potential adaptation to climate change options for the OECS and the wider Caribbean region.

B. POTENTIAL ADAPTATION MEASURES

Table 13 provides a comprehensive list of potential adaptation options that could be implemented in the Montserrat. The options are evaluated based on 10 criteria adopted from United States Agency for International Development (USAID) (2007). For example, in order to address the issue of increased wind speeds Montserrat could consider increasing the recommended design wind speed for new tourism structures. Some of the drawbacks of this approach, however, is that it would be quite costly, there may be a delay in relation to bringing the stock of infrastructure up to standard and could have negative implications for the competitiveness of the tourism product in the island over the short term. Nevertheless, such a policy has already been recommended by experts on the island and in a pilot study was quite effective. A similar type analysis was conducted for all the potential adaptation options outlined in Table 13.

⁶Given the relatively small contribution of islands such as Montserrat to global greenhouse gas emissions, mitigation is unlikely to be useful tool to address the issues surrounding global climate change. Consequently, this section of the study focuses primarily on adaptation to climate change.

Table 13: Potential Risks and Adaptation Options

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|---------------------------------------|---|--|---------------------|---------------|-------------------------------------|-------------------------------------|------------------------|------------|------------------------|-----------------------------|---|--------------------------------|
| | | | Cost | Effectiveness | Acceptability to Local Stakeholders | Acceptability to Financing Agencies | Endorsement by Experts | Time Frame | Institutional Capacity | Size of Beneficiaries Group | Potential Environmental or Social Impacts | Potential to Sustain over time |
| Increased wind speed | Greater number of category 4 and 5 hurricanes | Increase recommended design wind speeds for new tourism-related structures | X | X | | | X | X | | | X | X |
| | | Offer incentives to retrofit tourism facilities to limit the impact of increased wind speeds | | | | | | | | | X | |
| | | Retrofit ports to accommodate the expected rise in wind speeds | | X | | | X | | | | | |
| | | Catastrophe insurance for those government buildings that are used by tourists | | X | X | X | | | | | | |
| | | Insurance for adaptive rebuilding | | X | X | X | | | | | | |
| Decreased availability of fresh water | Increased frequency of droughts | Construction of water storage tanks | | | X | X | X | X | | | | |
| | | Irrigation network that allows for the recycling of waste water | | | X | X | X | | | X | X | |
| | | Retrofit hotels to conserve water | | X | X | X | X | | | | | |

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|-----------|----------------|---|---------------------|---------------|-------------------------------------|-------------------------------------|------------------------|------------|-------------------------|-----------------------------|---|--------------------------------|
| | | | Cost | Effectiveness | Acceptability to Local Stakeholders | Acceptability to Financing Agencies | Endorsement by Experts | Time Frame | Institution al Capacity | Size of Beneficiaries Group | Potential Environmental or Social Impacts | Potential to Sustain over time |
| | | Build desalination plants | | X | X | | | | | X | | |
| | | Drought insurance | | X | X | | | X | | | | |
| Land loss | Sea level rise | Build sea wall defences and breakwaters | | | X | | | | | X | X | |
| | | Replant mangrove swamps | | | X | | X | | | X | X | |
| | | Raise the land level of low lying areas | | | X | | | | | | | |
| | | Build tourism infrastructure further back from coast | X | X | | X | X | | | | X | |
| | | Beach nourishment | | | X | | | | | | | |
| | | Limit sand mining for building materials | X | X | | X | X | | | | X | |
| | | Introduce new legislation to change planning policies, zoning and land use priorities as needed | X | X | | | X | | | | X | |

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|---------------------|---|--|---------------------|---------------|-------------------------------------|-------------------------------------|------------------------|------------|-------------------------|-----------------------------|---|--------------------------------|
| | | | Cost | Effectiveness | Acceptability to Local Stakeholders | Acceptability to Financing Agencies | Endorsement by Experts | Time Frame | Institution al Capacity | Size of Beneficiaries Group | Potential Environmental or Social Impacts | Potential to Sustain over time |
| Loss of coral reefs | Inhibition of aragonite formation as carbonate-ion concentration s fall | Coral nurseries to help restore areas of the reef that have been damaged due to the effects of climate change | | X | | | X | | | X | X | |
| | | Enhanced reef monitoring systems to provide early warning alerts of bleaching events | X | X | X | X | X | | | X | X | X |
| | | Strengthen the scientific rigor and ecological relevance of existing water quality programs | X | X | X | X | X | | | X | X | X |
| | | Develop innovative partnerships with, and provide technical guidance to landowners and users to reduce land based sources of pollution | | X | | | X | | | | X | |
| | | Control discharges from known point sources such as vessel operations and offshore sewage | | X | | | X | | | | X | |
| | | Artificial reefs or fish-aggregating devices | | X | X | | X | | | X | X | |
| | | Enhancing coral larval recruitment | | X | X | | X | | | X | X | |
| | | Enhancing recovery by culture and transportation of corals | | X | X | | X | | | X | X | |

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|------------------------|----------------|--|---------------------|---------------|-------------------------------------|-------------------------------------|------------------------|------------|-------------------------|-----------------------------|---|--------------------------------|
| | | | Cost | Effectiveness | Acceptability to Local Stakeholders | Acceptability to Financing Agencies | Endorsement by Experts | Time Frame | Institution al Capacity | Size of Beneficiaries Group | Potential Environmental or Social Impacts | Potential to Sustain over time |
| | | Establish special marine zones | | X | | | X | | | X | X | |
| | | Implement pro-active plans to respond to non-native invasive species | | X | | | | | | | X | |
| Extreme weather events | Climate Change | Provide greater information about current weather events | X | X | X | X | X | X | X | X | | X |
| | | Develop national guidelines | X | X | X | X | X | X | X | X | X | X |
| | | Develop national evacuation and rescue plans | X | X | X | X | X | X | X | X | X | X |
| | | More stringent insurance conditions for the tourism industry | X | X | | | X | | | | | |
| | | Flood drainage protection for hotels | X | X | | | X | | | | | |
| | | Accelerated depreciation of properties in vulnerable coastal zones | | X | X | | X | | | | | |
| | | Supporting infrastructure investment for new tourism properties | | X | X | | | | | | | |

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|----------------------------|----------------|---|---------------------|---------------|-------------------------------------|-------------------------------------|------------------------|------------|-------------------------|-----------------------------|---|--------------------------------|
| | | | Cost | Effectiveness | Acceptability to Local Stakeholders | Acceptability to Financing Agencies | Endorsement by Experts | Time Frame | Institution al Capacity | Size of Beneficiaries Group | Potential Environmental or Social Impacts | Potential to Sustain over time |
| Reduction in travel demand | Climate Change | Increase advertising in key source markets | | X | X | | X | X | | | | |
| | | Fund discount programmes run by airlines | | X | X | | X | X | | | | |
| | | Fund discount programmes run by hotels | | X | X | | X | X | | | | |
| | | Introduce "green certification" programmes for hotels | | X | X | | X | | | | | |
| | | Conducting energy audits and training to enhance energy efficiency in the industry | | X | | | X | | | | | |
| | | Introduce built attractions to replace natural attractions | | X | | | X | | | X | | |
| | | Recognition of the vulnerability of some eco-systems and adopt measures to protect them | | X | | | X | | | | X | |
| | | Introduction of alternative attractions | | X | X | | X | | | X | X | |
| | | Provide re-training for displaced tourism workers | | X | X | | X | X | | X | | |

| Risks | Source | Risk mitigation or transfer options | Evaluation Criteria | | | | | | | | | |
|-------|--------|---|---------------------|----------------------|--|--|-------------------------------|-------------------|--------------------------------|------------------------------------|---|---------------------------------------|
| | | | <i>Cost</i> | <i>Effectiveness</i> | <i>Acceptability to Local Stakeholders</i> | <i>Acceptability to Financing Agencies</i> | <i>Endorsement by Experts</i> | <i>Time Frame</i> | <i>Institution al Capacity</i> | <i>Size of Beneficiaries Group</i> | <i>Potential Environm ental or Social Impacts</i> | <i>Potential to Sustain over time</i> |
| | | Revise policies related to financing national tourism offices to accommodate the new climatic realities | X | X | X | | X | X | | | | |

C. COST-BENEFIT ANALYSIS OF SHORT-LISTED OPTIONS

Gray (2010), through consultations with key stakeholders, identified the following as key areas of national concern as they relate to adapting to climate change: coastal zone management, water resources, agriculture, fisheries, forestry and biodiversity, tourism, access to critical infrastructure, marine biodiversity and human settlements. The report therefore recommended the following adaptation policies: the establishment of setbacks, utilisation of tapped springs presently not in use, abandonment of unproductive land, relocation of hotels and other tourism infrastructure, relocation of critical infrastructure at risk, construction of a deep sea sewage outfall to ensure adequate dispersion, relocation of vulnerable roads and relocation of existing utilities underground.

Based on the evaluation criteria provided in section 6.2 as well Gray (2010) report, a short-list of potential mitigation options was derived. These recommendations are also consistent with the Smith Warner International (Smith Warner International, 2003). These included:

- (a) Increased recommended design wind speeds for new tourism-related structures;
- (b) Construction of water storage tanks;
- (c) Irrigation network that allows for the recycling of waste water;
- (d) Enhanced reef monitoring systems to provide early warning alerts of bleaching events;
- (e) Deployment of artificial reefs or fish-aggregating devices;
- (f) Develop national evacuation and rescue plans;
- (g) Introduction of alternative attractions;
- (h) Provide re-training for displaced tourism workers, and;
- (i) Revise policies related to financing national tourism offices to accommodate the new climatic realities

Table 14 provides a summary of the cost-benefit analyses conducted for the study (see the Annex for the description of the costs and benefits of each option). Of the nine options considered three had cost-benefit ratios above 1 over a 20-year horizon: option 1, option 4 as well as option 5. While some of the other options may have ratios below 1, once non-tangible benefits are included in the analysis, it is quite likely that these ratios might easily rise above 1. For example, while retraining workers might not be cost effective, in terms of the well-being of the country's citizens, the option might still be considered viable.

Table 14:
Cost-benefit analysis of selected options

| US\$ Mil | Details | 1% discount rate | | 2% discount rate | | 4% discount rate | |
|----------|---|--------------------------|------------------------------|--------------------------|------------------------------|--------------------------|------------------------------|
| | | Benefit Cost Ratio | Payback Period (years) | Benefit Cost Ratio | Payback Period (years) | Benefit Cost Ratio | Payback Period (years) |
| Option 1 | Increase recommended design wind speeds for new tourism-related structures | 1.5 | 14 | 1.4 | 14 | 1.3 | 15 |
| Option 2 | Construction of water storage tanks | 0.4 | - | 0.4 | - | 0.4 | - |
| Option 3 | Irrigation network that allows for the recycling of waste water | 0.3 | - | 0.3 | - | 0.3 | - |
| Option 4 | Enhanced reef monitoring systems to provide early warning alerts of bleaching events | 4.5 | 3 | 4.4 | 3 | 4.0 | 3 |
| Option 5 | Artificial reefs or fish-aggregating devices | 1.9 | 6 | 1.8 | 7 | 1.7 | 7 |
| Option 6 | Develop national evacuation and rescue plans | 0.9 | - | 0.9 | - | 0.8 | - |
| Option 7 | Introduction of alternative attractions | 0.0 | - | 0.0 | - | 0.0 | - |
| Option 8 | Provide re-training for displaced tourism workers | 0.4 | - | 0.4 | - | 0.4 | - |
| Option 9 | Revise policies related to financing national tourism offices to accommodate the new climatic realities | 0.1 | - | 0.1 | - | 0.1 | - |

Source: Data compiled by author

VII. CONCLUSIONS

Within recent years, Montserrat has actively marketed the island as an ideal destination for individuals from North America and Europe looking for an authentic Caribbean experience. Consequently, the island has become very dependent on the tourist industry; in Montserrat, earnings from tourism were more than five times its merchandise exports. The emergence of tourism as a viable industry has been fortuitous given that this small overseas territory of the United Kingdom is just now trying to recover after the eruption of the Soufriere Hills volcano in 1995.

The tourist industry is now an integral component in relation to generating jobs and maintaining the livelihoods of individuals on the island; consequently, it is important to monitor and effectively address all potential threats. One such threat changes in global climatic patterns. A shift in global climatic patterns can be potentially devastating to small states given the intrinsic vulnerability of small islands and their infrastructure, the dependence of the regional tourist industry on carbon-based fuels to

transport individuals to and from the region as well as the climatic features that make the Caribbean an ideal tourist destination.

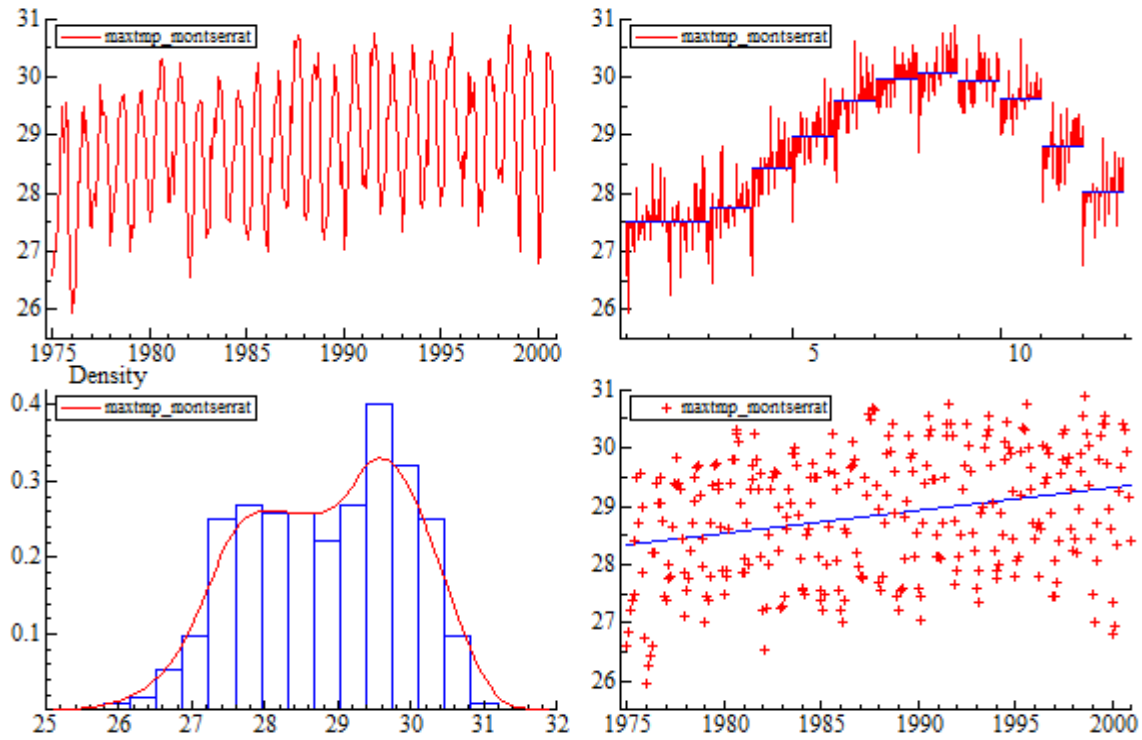
This study therefore, provides an assessment of the likely effects of climate change on the tourism product in Montserrat. A TCI, which measures the effects that climate can have on a visitor's experience, was calculated using historical data as well as the likely climatic future under the A2 and B2 scenarios. The results imply that the TCI was likely to experience a significant downward shift under the A2 as well as B2 scenarios; indicative of deterioration in the suitability of the island for tourism. It is estimated that this shift in tourism features could cost Montserrat about 145% of 2009 GDP over a 40-year horizon.

In addition to changes in the climatic suitability for tourism, climate change is also likely to have important supply-side effects on species, ecosystems and landscapes. Two broad areas are considered in this study: (a) coral reefs, due to their intimate link to tourism, and; (b) land loss, as most hotels tend to be located along the coastline. In Montserrat, the estimated value of damage due to the loss of coral reefs was estimated at 7.6 times 2009 GDP, while the costs associated with land loss for the tourism industry were 47% of 2009 GDP. The costs due to the loss of coral reefs and land therefore seem to swamp any anticipated demand-side changes. The total cost of climate change for the tourism industry was therefore projected to be 9.6 times 2009 GDP if nothing is done to adapt to the likely effects of climate change.

Given the potential for significant damage to the industry a large number of potential mitigation measures were considered. Out of these a short-list, nine potential options were selected using 10 evaluation criteria. Using benefit-cost analyses three options were put forward: (a) increase recommended design speeds for new tourism-related structures; (b) enhanced reef monitoring systems to provide early warning alerts of bleaching events, and; (c) deployment of artificial reefs or fish-aggregating devices. While these options had positive benefit cost ratios, other options were also recommended based on their non-tangible benefits: irrigation network that allows for the recycling of waste water, development of national evacuation and rescue plans, providing retraining for displaced tourism workers and the revision of policies related to financing national tourism offices to accommodate the new climatic realities.

Annex

Figure 11:
Historical average daily maximum temperature – Montserrat



Source: Data compiled by author

Figure 12:
Historical average daily relative humidity – Montserrat

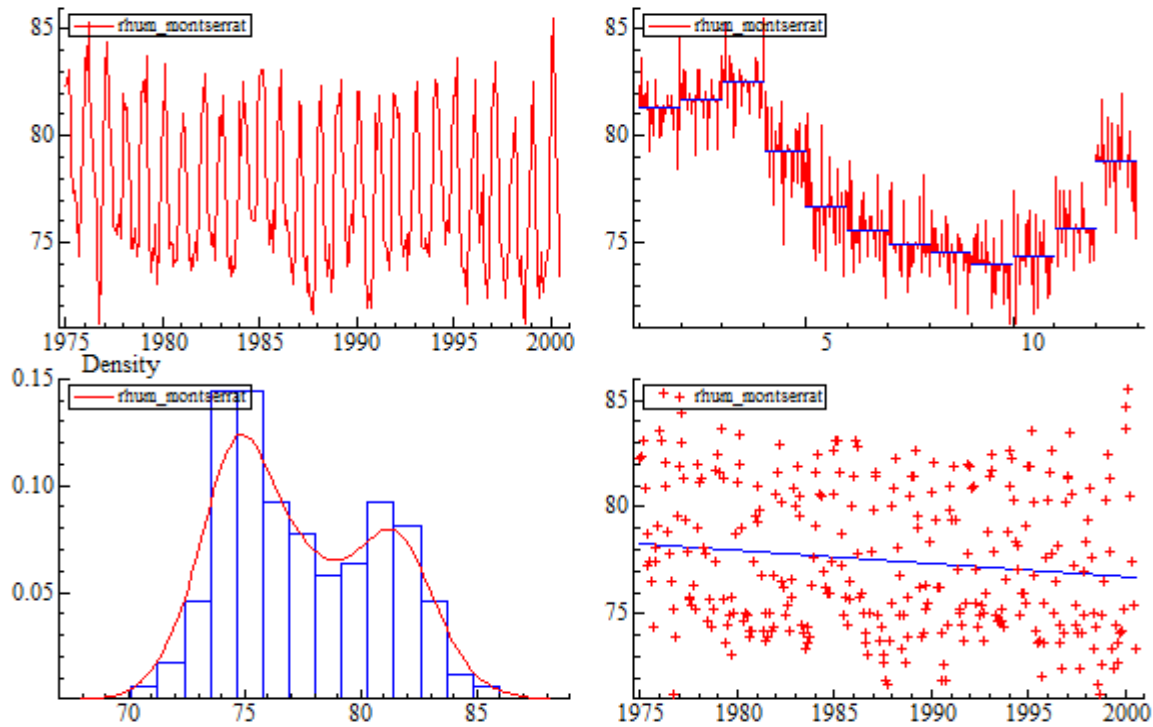
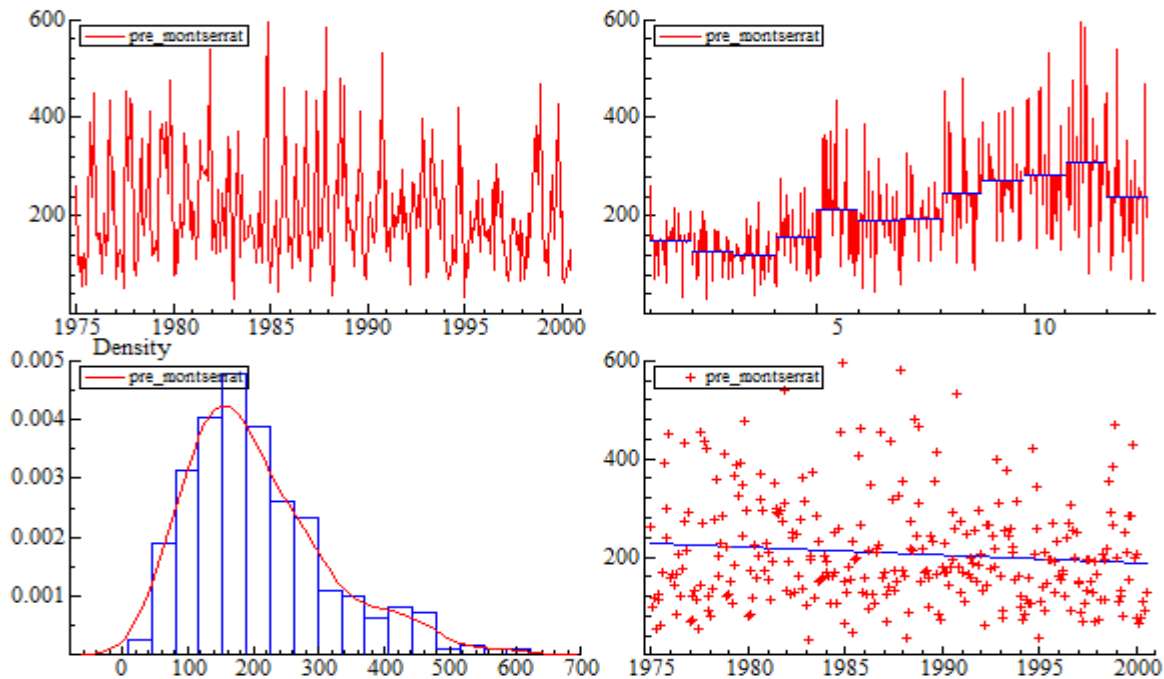
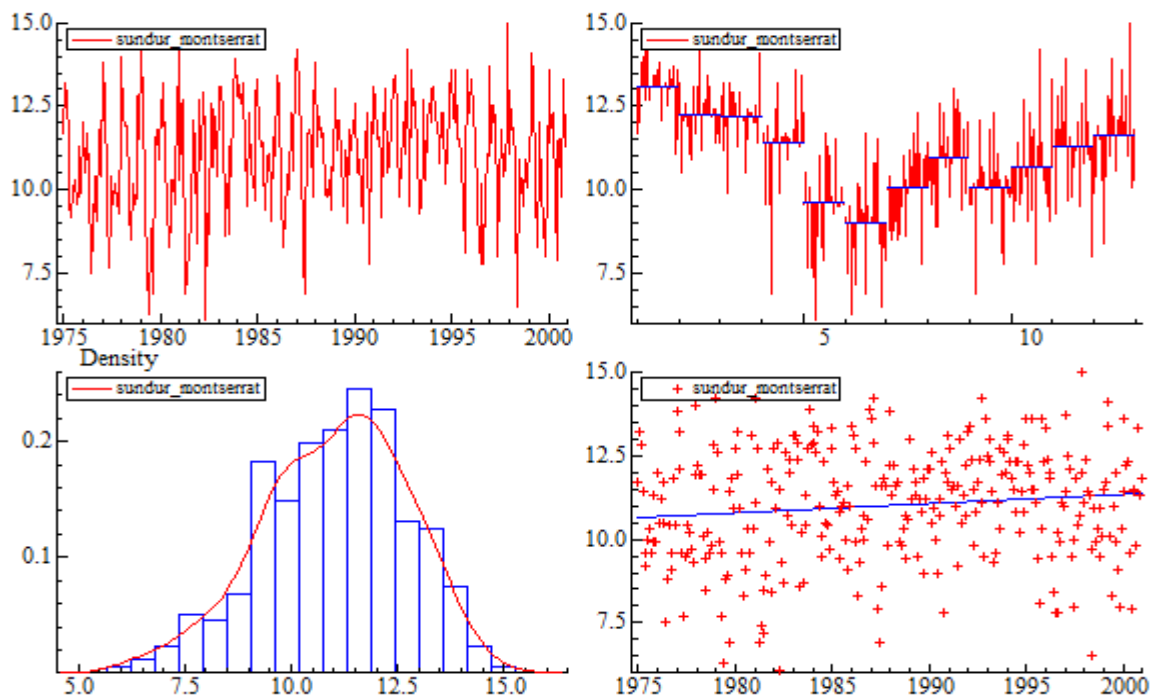


Figure 13:
Historical average monthly precipitation – Montserrat



Source: Data compiled by author

Figure 14:
Historical average sun duration – Montserrat



Source: Data compiled by author

Table 15:
Details of cost-benefit scenarios

| | Summary and Assumptions |
|--|--|
| Option 1: Design Speeds for New Tourism Properties | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from introducing legislation to require that all new tourism establishments design properties to withstand tropical cyclones.</p> <p>In the cost benefit analysis the estimated tangible benefits are cost avoidance or damage reduction estimated at 1% of GDP in year 5 of the analysis and 5% of GDP from year 10 onwards. The cost savings are derived from the damage estimates discussed in the paper. The relatively low cost reductions in the early years of the cost-benefit analysis are to account for the relatively low penetration rate in the early years.</p> <p>The tangible costs are related to the additional building costs likely to be incurred as a result of such a policy. These are estimated at 3% of gross capital formation (or the proportion of new investment accruing to tourism), while implementation and other costs are estimated at 40% of the additional building costs.</p> |
| Option 2: Water Storage Tanks | <p>This scenario provides a cost benefit analysis of the potential benefits accruing to the island from introducing legislation requiring that all new tourism establishments install water tanks.</p> <p>In the cost benefit analysis the estimated tangible benefits is the provision of water during droughts and is estimated at 10% of water consumption multiplied by the tariff rate. Given that a drought is unlikely to occur every year, a drought probability is applied to this estimate which works out to about two about two droughts every 20 year period.</p> <p>The tangible costs are related to building/purchasing these tanks as well as maintenance and other installation expenses. Using www.rainwatertanksdirect.com it is estimated that a 25000L tank would cost approximately US\$50,000 and 1365 tanks would be needed to supply the tourist industry. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 1% of the capital investment.</p> |
| Option 3: Recycling Water | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from introducing legislation to require that new tourism establishments design properties to recycle water (but not to potable level).</p> <p>In the cost-benefit analysis the estimated tangible benefits are cost avoidance or 15% of water consumption multiplied by the tariff per litre.</p> <p>The tangible costs are related to the additional building costs likely to be incurred as a result of such a policy. Based on the paper “The Cost of Wastewater Reclamation and Reuse in Agriculture Production in Mediterranean Countries” it is estimated that plant costs are US\$50 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the capital investment.</p> |
| Option 4: Enhanced Reef Monitoring Systems | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from enhancing the reef monitoring system.</p> <p>In the cost-benefit analysis the estimated benefit is the value of coral reefs saved is 5% of the reef losses under the B2 scenario. Implementation costs are related to the cost of developing the system and these are set at \$5 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 20% of the capital investment.</p> |
| Option 5: Artificial Reefs | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from using artificial reefs to offset coral reef losses expected under the climate scenarios.</p> |

| | Summary and Assumptions |
|--|--|
| | <p>In the cost-benefit analysis the estimated that the value of coral reefs saved is 5% of the reef losses under the B2 scenario.</p> <p>The tangible costs are largely driven by the implementation costs: each artificial reef costs US\$60,000 (see www.lbara.com/history.htm) for 200 sites (see edis.ifas.ufl.edu/fe649). Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the capital investment.</p> |
| Option 6: National Rescue Plans | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from implementing national rescue plans.</p> <p>In the cost-benefit analysis the estimated benefit is the value of property saved: 30% of property losses under the B2 scenario. Implementation costs are related to the cost of developing the system and these are set at \$10 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the initial capital investment.</p> |
| Option 7: Development of Alternative Attractions | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from developing alternative attractions that leverage other natural assets besides sun, sea and sand.</p> <p>In the cost-benefit analysis the estimated that the additional expenditure is 10% of tourism losses under the B2 scenario multiplied by average visitor expenditure. Implementation costs are related to the cost of developing the attraction and are set at \$10 million. Maintenance costs are 5% of the initial investment, while installation costs are estimated at 10% of the initial capital investment.</p> |
| Option 8: Retraining Tourism Workers | <p>This scenario provides a cost-benefit analysis of the potential benefits accruing to the island from retraining tourism workers.</p> <p>In the cost-benefit analysis the tangible benefits are the non-incurred unemployment claims estimated at \$12,000 (average salary) * 200 workers. Implementation costs are related to the cost of developing the system and are set at \$10 million. Annual training costs are \$30,000*200 workers as well as additional set-up costs estimated at 10% of the initial capital investment.</p> |
| Option 9: Revise Policies at National Tourism Offices and Consulates | <p>This scenario provides a cost-benefit analysis of revising the policies of National Tourism Offices and Consulates to Account for the new climate realities.</p> <p>In the cost-benefit analysis the additional tourist expenditure is 10% of tourism losses under the B2 scenario multiplied by average visitor expenditure.</p> <p>Implementation costs are related to the cost of developing these plans and policies are set at \$3 million. Additional marketing costs are estimated at 2 million in first year and increase by 4% per annum thereafter. Additional set-up costs are estimated at 20% of the initial capital investment.</p> |

REFERENCES

- Amelung, B., Nicholls, S., & Viner, D. (2007). Implications of Global Climate Change for Tourism Flows and Seasonality. *Journal of Travel Research*, 45 (3), 285-296.
- Aronson, R. B., Precht, W. F., Macintyre, I. G., & Murdoch, T. J. (2000). Ecosystems: Coral Bleach-Out in Belize. *Nature*, 405 (6782), 36.
- Beniston, M. (2003). Climate Change in Mountain Regions: A Review of Possible Impacts. *Climatic Change*, 59 (1-2), 5-31.
- Beukering, P., Brander, L., Immerzeel, D., Leotaud, N., Mendes, S., Soesbergen, A., et al. (2008). *Value After the Volcano: Economic Valuation of Montserrat's Centre Hills*. Bedfordshire: Royal Society for the Protection of Birds.
- Bishop, M. L. (2010). Tourism as a Small-State Development Strategy: Pier Pressure in the Eastern Caribbean. *Progress in Development Studies*, 10 (2), 99-114.
- Black, B. A., Schroeder, I. D., Sydeman, W. J., Bograd, S. J., & Lawson, P. W. (2010). Wintertime Ocean Conditions Synchronize Rockfish Growth and Seabird Reproduction in the central California Current Ecosystem. *Canadian Journal of Fisheries and Aquatic Sciences*, 67 (7), 1149.
- Burke, L., Greenhalgh, S., Prager, D., & Cooper, E. (2008). *Coastal Capital: Economic Valuation of Coral Reefs in Tobago and St. Lucia*. Washington, DC: World Resources Institute.
- Cane, A. M. (2005). The Evolution of El Nino, Past and Future. *Earth and Planetary Science Letters*, 230 (3-4), 227-240.
- Chand, S. S., E, W. K., & Chan, J. C. (2010). A Bayesian Regression Approach to Seasonal Prediction of Tropical Cyclones Affecting the Fiji Region. *Journal of Climate*, 23 (13), 3425-3446.
- Clayton, A. (2009). Climate Change and Tourism: The Implications for the Caribbean. *Worldwide Hospitality and Tourism Themes*, 1 (3), 212-230.
- Collins, M. (2000). The El Nino - Souther Oscillation in the Second Hadley Centre Coupled Model and its Response to Greenhouse Warming. *Journal of Climate*, 13 (7), 1299-1312.
- Crick, A. P. (2003). Internal Marketing of Attitudes in Caribbean Tourism. *International Journal of Contemporary Hospitality Management*, 15 (3), 161-166.
- CTO. (Various Issues). *Caribbean Statistical Report*. Bridgetown: Caribbean Tourism Organisation.
- de Albuquerque, K., & McElroy, J. (1995). Planning for Effective Management and Sustainable Development of Coastal Resources in Caribbean Small Island States. *Caribbean Dialogue*, 2 (1), 11-16.
- de Freitas, C. R. (2003). Tourism Climatology: Evaluating Environmental Information for Decision Making and Business Planning in the Recreation and Tourism Sector. *International Journal of Biometeorology*, 48 (1), 45-54.
- Deslandes, D. (2006). Assessing the Image of St. Lucia: Does the Type of Visitor Matter? *Journal of Eastern Caribbean Studies*, 31 (4), 53-84.

ECCB. (2009). *Annual Economic and Financial Review*. Basseterre, St. Kitts and Nevis: Eastern Caribbean Central Bank.

Emmanuel, K., & Spence, B. (2009). Climate Change Implications for Water Resource Management in the Caribbean. *Worldwide Hospitality and Tourism Themes*, 1 (3), 252-268.

GCSI. (2002). *Assessment of the Economic Impact of Climate Change on CARICOM Countries*. World Bank, Environment and Socially Sustainable Development - Latin America and the Caribbean. Toronto: Global Change Strategies International.

Gill, J. A., Watkinson, A. R., McWilliams, J. P., & Cote, I. M. (2006). Opposing Forces of Aerosol Cooling and the El Nino Drive Coral Bleaching on Caribbean Reefs. *Proceedings of the National Academy of Sciences of the United States of America*, 103 (49), 18870.

Government_of_Saint_Lucia. (2005 йил 19-January). *St. Lucia National Climate Change Policy and Adaptation Plan*. Retrieved 2010 йил 13-October from Climate Change Website of St. Lucia: http://www.climatechange.gov.lc/NCC_Policy-Adaptation_7April2003.pdf

Gray, G. A. (2010). *National Climate Change Issues Paper: Towards the Formulation of a National Climate Change (Adaptation) Policy and Action Plan*. Department of Environment. Brades: Ministry of Agriculture, Land, Housing and the Environment.

Griffith, A. (2001). *The Characteristics of Water Use in Three Residential Areas in Barbados Implications for a Conservation Strategy*. unpublished MSc dissertation, University of the West Indies, Kingston.

Hamilton, J. M., & Lau, M. A. (2005). The Role of Climate Information in Tourist Destination Choice Making. In S. Gossling, & M. C. Hall, *Tourism and Global Environmental Change* (Vol. 1, pp. 229-250). Routledge.

Harrison, S. J., Winterbottom, S. J., & Sheppard, C. (1999). The Potential Effects of Climate Change on the Scottish Tourist Industry. *Tourism Management*, 20 (2), 203-211.

Harvey, A. C. (1989). *Forecasting Structural Time Series and Kalman Filter*. Cambridge: Cambridge University Press.

Hein, L. (2007). *The Impact of Climate Change on Tourism in Spain*. Blindern: Centre for International Climate and Environmental Research.

Hoegh-Guldberg, O. e. (2007). Coral Reefs Under Rapid Climate Change And Ocean Acidification. *Science*, 318, 1737-1742.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J., Steneck, R. S., Greenfield, P., Gomez, E., et al. (2007). Coral Reefs Under Rapid Climate Change And Ocean Acidification. *Science*, 318, 1737-1742.

Kaars, S., Tapper, N., & Cook, E. J. (2010). Observed Relationships between El Nino-Southern Oscillation, Rainfall Variability and Vegetation and Fire History on Halmahera, Maluku, Indonesia. *Global Change Biology*, 16 (6), 1705.

Koenig, U., & Abegg, B. (1997). Impacts of Climate Change on Winter Tourism in the Swiss Alps. *Journal of Sustainable Tourism*, 5 (1), 46-58.

- Koopman, S. J., Harvey, A. C., Doornik, J. A., & Shephard, N. (2009). *Structural Time Series Analyser, Modeller and Predictor*. London: Timberlake Consultants Ltd.
- Kossin, J. P., Camargo, S. J., & Sitkowski, M. (2010). Climate Modulation of North Atlantic Hurricane Tracks. *Journal of Climate*, 23 (11), 3057-3077.
- Landsea, C. W., Pielke, R. A., Mestas-Nunez, A. M., & Knaff, J. A. (1999). Atlantic Basin Hurricanes: Indices of Climatic Change. *Climate Change*, 42, 89-129.
- Latimer, H. (1985). Developing-Island Economies – Tourism v. Agriculture. *Tourism Management*, 6 (1), 32-42.
- Lee, C. K., Var, T., & Blaine, T. W. (1996). Determinants of Inbound Tourist Expenditures. *Annals of Tourism Research*, 23 (3), 527-542.
- Lise, W., & Tol, R. S. (2002). Impact of Climate on Tourist Demand. *Climatic Change*, 55 (4), 429-449.
- Magnusson, W. E., Layme, V. M., & Lima, A. P. (2010). Complex Effects of Climate Change: Population Fluctuations in a Tropical Rodent are Associated with the Southern Oscillation Index and Regional Fire Extent, but not Directly with Local Rainfall. *Global Change Biology*, 19 (9), 2401.
- Malmgren, B. A., Winter, A., & Chen, D. (1998). El Nino-Southern Oscillation and North Atlantic Oscillation control of climate in Puerto Rico. *Journal of Climate*, 11 (10), 2713-2718.
- Mieczkowski, Z. (1985). The Tourism Climatic Index: A Method of Evaluating World Climates for Tourism. *Canadian Geographer*, 29 (3), 220-233.
- Mihalic, T. (2002). Tourism and Economic Development Issues. In R. Sharply, & D. J. Telfer, *Tourism and Development: Concepts and Issues* (pp. 81-111). Clevedon: Channel View Publications.
- Mitchell, T. D., Carter, T. R., Jones, P. D., Hulme, M., & New, M. G. (2004). *A Comprehensive Set of High-Resolution Grids of Monthly Climate for Europe and the Globe: The Observed Record (1901-2000) and 16 Scenarios (2001-2100)*. Norwich, UK: Tyndall Centre.
- Modeste, N. C. (1995). The Impact of Growth in the Tourism Sector on Economic Development: The Experience of Selected Caribbean Countries. *International Economics*, 48 (3), 375-385.
- Moore, W. R. (2010). The Impact of Climate Change on Caribbean Tourism Demand. *Current Issues in Tourism*, 13 (5), 495-505.
- Moore, W. R., Harewood, L., & Grosvenor, T. (2010). *The Supply Side Effects of Climate Change on Tourism*. Germany: University Library of Munich.
- Pachauri, R. K., & Reisinger, A. (2007). *Climate Change 2007: Synthesis Report*. Geneva: Intergovernmental Panel on Climate Change.
- Rohr, J. R., & Raffel, T. R. (2010). Linking Global Climate and Temperature Variability to Widespread Amphibian declines Putatively caused by Disease. *Proceedings of the National Academy of Sciences of the United States of America*, 107 (18), 8269.

Sanders, R. (2010 йил 2-August). *Trinidad Express*. Retrieved 2010 йил 25-August from <http://www.trinidadexpress.com/commentaries/99738789.html>

Scott, D., & McBoyle, G. (2001). Using a Tourism Climate Index to Examine the Implications of Climate Change for Climate as a Tourism Resource. In A. Matzarakis, & C. R. de Freitas, *Proceedings of the First International Workshop on Climate, Tourism and Recreation* (pp. 69-88). Freiburg: International Society of Biometeorology.

Scott, D., Gossling, S., & de Freitas, C. R. (2007). Climate Preferences for Tourism: An Exploratory Tri-Nation Comparison. In A. Matzarakis, C. R. de Freitas, & D. Scott, *Developments in Tourism Climatology* (pp. 18-23). Freiburg: International Society of Biometeorology.

Simpson, M. C., Scott, D., Harrison, M., Silver, N., O'Keeffe, E., Sim, R., et al. (2010). *Quantification and Magnitude of Losses and Damages Resulting from the Impacts of Climate Change: Modelling the Transformational Impacts and Costs of Sea Level Rise in the Caribbean (Summary Document)*. Bridgetown: United Nations Development Programme.

Smith Warner International. (2003). *Integrated Vulnerability Assessment of Montserrat*. Brades: Government of Montserrat.

Tartaglione, C. A., Smith, S. R., & O'Brien, J. J. (2003). ENSO Impact on Hurricane Landfall Probabilities for the Caribbean. *Journal of Climate*, 16 (17), 2925.

Timmermann, A., Oberhuber, J., Bacher, A., Esch, M., Latif, M., & Roeckner, E. (1999). Increased El Nino Frequency in a Climate Model Forced by Future Greenhouse Warming. *Nature*, 398, 694-697.

Tol, R. S. (2002). Estimates of the Damage Costs of Climate Change. *Environmental and Resource Economics*, 21 (1), 47-73.

USAID. (2007). *Adapting to Climate Variability and Change: A Guidance Manual for Development Planning*. Retrieved 2010 йил 13-October from US Agency for International Development: http://www.usaid.gov/our_work/environment/climate/docs/reports/cc_vamannual.pdf

Uyarra, M. C., Cote, I. M., Gill, J. A., Tinch, R. R., Viner, D., & Watkinson, A. R. (2005). Island-Specific Preferences of Tourists for Environmental Features: Implications of Climate Change for Tourism-Dependent States. *Environmental Conservation*, 32 (1), 11-19.

Wallace, D. J., & Anderson, J. B. (2010). Evidence of Similar Probability of Intense Hurricane Strikes for the Gulf of Mexico over the Late Holocene. *Geology*, 38 (6), 511.

Westra, S., & Sharma, A. (2010). An Upper Limit to Seasonal Rainfall Predictability? *Journal of Climate*, 23 (12), 3332-3352.

Xie, S.-P., Du, Y., Huang, G., & Zheng, X.-T. (2010). Decadal Shift in El Nino Influences on Indo-Western Pacific and East Asian Climate in the 1970s. *Journal of Climate*, Vol. 23 (12), 3352-3369.

Yocom, L. L., Fule, P. Z., Brown, P. M., Cerano, J., Villaneueva-Diaz, J., Falk, D. A., et al. (2010). El Niño-Southern Oscillation effect on a fire regime in northeastern Mexico has changed over time. *Ecology*, 91 (6), 1660.

Zhan, W.-Y., Guo, W.-D., Fang, L.-Q., & Li, C.-P. (2010). Climate Variability and Hemorrhagic Fever with Renal Syndrome Transmission in Northeastern China. *Environmental Health Perspectives*, 118 (7), 915-921.

Zhuang, J., Liang, Z., Lin, T., & De Guzman, F. (2007). *Theory and Practice in the Choice of Social Discount Rate for Cost-Benefit Analysis: A Survey*. Mandaluyong City: Asian Development Bank.