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

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Executive Summary

The Bahamas is at great risk and vulnerability given its geographical features as a low-lying, sea encircled country. If projected sea level rise is reached by 2050, between 10-12% of territory will be lost, especially in coastal zones where the main tourism assets are located. Vulnerability could also be manifested if flight carbon emission taxes are established in the main source markets, representing an economic threat to the tourism sector for the islands.

The impact of climate change on main tourism demand variables will cause some losses to the country's income and government revenues. This would be acting conjointly with some local threats to tourism assets and trends in future global tourism demand.

The second and no less important threat is tropical cyclones, which may be associated with raising sea level. Estimations posited the amount of losses in excess of 2400 million US$ for the four decades under examination. It is to be pointed out that there is still a lack of comparatively accurate data collection and analysis on this subject, a point deserving more attention in order to deepen the understanding of, and to extract better lessons from these extreme events.

In the same period, total estimated impacts of progressive climate change are between 17 and 19 billions of B$ with estimated discount rates applied.

The Bahamas is a Small Island Developing State with low growth on GHG emissions (second in Latin America), as well as a relative short capacity to lower emissions in the future. The country has a relative delay in the application of renewable energy systems, a solution that, provided documented studies on-site, might turn out to be fundamental in the country's efforts to establish mitigation related policies.

The Bahamas currently has institutions and organizations that deal with climate change-related issues and an important number of measures and courses of action have been set up by the government. Nevertheless, more coordination among them is needed and should include international institutions. This coordination is essential even for the first steps, i.e. to conduct studies with a bottom-up approach in order to draw more accurate programs on adaptation and mitigation.

It is fundamental for tourism to keep track of potential losses in tourist attractions (and to act accordingly), related to correspondent losses in biodiversity, water resources and coastal erosion. Also, actions to fight climate change impacts might improve the islands security standards, quality of living and protect cultural and heritage assets. These elements may definitely shape the future of the country's competitiveness as a tourism destination.

It is possible and necessary to decide about the options with good cost-benefit ratio and reasonable payback periods, notwithstanding that cost-benefit analysis requires more refined and accurate data to provide precise and locally adapted options.

I. INTRODUCTION

The process of analyzing climate change, its physical basis, economic impacts and countermeasures is one of the most important issues for governments. Depending on the success of mitigating its effects, the future of forthcoming generations will or will not be guaranteed. Regarding these matters, the Economic Commission for Latin America and the Caribbean (ECLAC) and the Inter-American Development Bank (ECLAC-IDB 2010) are leading a group of studies on economic impact of climate change in the countries of the Caribbean region. One of them is a recent study prepared for the Latin American and Caribbean Unity Summit. It expressed (ECLAC-IDB 2010:10):

"The global climate has been evolving since the formation of the Earth itself, basically due to natural causes. From the nineteenth century onwards however, the generation of GHG's as a result of human activity has raised the average temperature to such an extent that it is now at its highest in 1,000 years, having increased by 0.7 degrees Celsius between 1850-1899 and 2001-2005[1]. The world's precipitation patterns have already been observably modified, the intensity of the hydrological cycle and extreme weather events is increasing, sea levels are rising and the ice caps are receding (IPCC 2007)".

"The tourist sector is recognized as the key engine of growth in the Caribbean, representing a significant source of foreign exchange earnings and employment" (Moore and others (2010), that is, tourism and tourism-related activities constitute an important part of national economies in the Caribbean region. On the other hand, a growing amount of studies, both government and independently funded, have assessed the importance of taking into account the climate change-originated processes for the future of the tourism sector in the area and particularly for The Bahamas, one of the Small Island Developing States, classified by the United Nations. McElroy (2006), classifies SIDS, whose economies are heavily dependant on tourisms as "Small Island Tourism Economies" as is the case of the Bahamas. These states have a remote probability of becoming large emitters of GHGs even in the long term. Another issue is the link between present day decision making pertaining to climate change and long term results to forthcoming generations. Climate change represents high risk for SIDS: they could disappear in a short period of time if the sea level rises as is foreseen.

The main objective of this report is to establish an approach to analyze main focal points of climate change on components of the Bahamian tourism sector (demand and supply sides) through major impacts on visitor arrivals, tourism expenditure, tourism attraction losses and other losses in related sectors and to present a brief list of investment opportunities for both adaptation and mitigation actions using Cost-Benefit Analysis.

To accomplish this task, impacts of climate change on the sector are analyzed from the point of view of tourism as an economic activity, rather than from a more individual, socio-psychological outlook. Accordingly, the main focal points of attention and action are divided into two categories or parts of the equation: demand and supply side. As in all economic analysis, these categories, although separate in themselves are also strongly related.

Section II brings a review of the Interaction between climate change and the tourism sector. Later, it is presented main physical impacts and the economic background for The Bahamas with a special consideration of climate change and the tourism sector. Section III discusses the database and models employed in this study. Section IV discusses the results of modelling of visitor arrivals and tourism

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[1] Greenhouse gases are gases that retain heat and raise the Earth's temperature in the same way that a greenhouse heats air close to the ground. The four main greenhouse gases are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and Sulphur hexafluoride (SF6). Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs) make up another important group of greenhouse gases.

expenditures, bringing an assessment of costs for each scenario. A particular scenario to include losses due to extreme events is also outlined and a summary of economic impacts (both by modelling and from extreme events) is presented. Section V presents a comprehensive list of actions for adaptation and mitigation, including cost-benefit analysis for a short-list selected. Lastly, Section VI concludes with some recommendations.

II. CLIMATE CHANGE AND TOURISM

A. CLIMATE CHANGE FEATURES

Through extensive literature review, it has been determined that the main consideration of climate change is the following effects:

- Temperature increase
- Rainfall and relative humidity decrease or increase
- Extreme events intensity increase
- Sea level rise
- Ocean acidification
-

Mean temperature increase has been observed in the latter part of the 20th century globally and throughout the Caribbean Basin (Mimura and others, 2007). According to the Simpson and others (2009), regional temperature increase is expected in this century for all IPCC Special Reduction Emission Scenarios (SRES), with at least a ~0.7 °C increase in the area by the time the 2.0 °C threshold have been reached at a global level. Generally speaking, decreasing average rainfall should range between 5-10%, again at the globally reached 2. 0 °C threshold, but precipitation has a distinct pattern and forecast for the region in that a general decrease in rainfall measures is expected, except perhaps for The Bahamas and Bermuda.

Although still a widely discussed issue in the literature, tropical cyclone (TC) activity has been linked to climate change in several studies (Lighthill and others, 1994, Enmanuel and others, 2008). Results show that there has been an intensified destructive impact of TC in the past decades (Enmanuel, 2005), and projections concur that this trend is likely to hold in the current century, as it was considered by the IPCC (2007). Knutson and others (2010) concluded that "anthropogenic warming over the next century more likely than not will lead to substantial fractional increases in the numbers of very intense hurricanes in some basins, despite a likely decrease (or little change) in the global numbers of tropical storms"**.** It is worth noting that here "more likely than not" means a probability of occurrence between 50 and 66 percent.

The models developed in Knutson and others (2010) projected that occurrence of category 4-5 hurricanes (in a Saffir-Simpson scale of 5 levels) in the North Atlantic coast (between the United States of America and The Bahamas) will increase notably in this century. There is a lot of less agreement on the frequency of TC in the future, though a certain decrease is widely accepted (Simpson and others, 2009).

Tidal gauge and satellite altimetry have provided the means to affirm that sea level rise is accelerating at both global and regional scales, following Meehl and others (2007) and Simpson and others (2010). This rise is caused mainly by two factors related to global warming: oceans expansion and ice shelves calving and melting. The former is a physical consequence of heat, while the later has multiple causes, including issues like local lower albedo, which through a feedback process increases local temperature. Moreover, Bamber and others (2009) state that there is a likely chance that the Caribbean

Basin sea level rise will surpass global levels, due mainly to geographical and gravitational conditions, on a rate of more than 25%.

Deriving from the fact that sea is net absorber of CO_2 and, in a much lesser way, of SO_2, growing numbers of GHG emissions have result in an increasingly lowering of the oceans' pH. This process, known as ocean acidification and colloquially as "the other" impact of climate change, has accelerated in this century, at rates that supersede both precedent and predicted values (NRC 2010a). Ocean acidification can be locally increased by ocean cloud phenomena, due also to lower local albedo, as a positive feedback cycle stated in the anti-CLAW hypothesis (Lovelock, 2007).

To study the impacts of climate change in economies and societies, team writers of the IPCC worked on the Special Report on Emissions Scenarios (SRES) since 1997. The IPCC (2000) stated that "The primary purpose of developing multiple scenario families was to explore the uncertainties behind potential trends in global developments and GHG emissions, as well as the key drivers that influence these". Four brief "future histories" captured by the SRES storylines differ in how global regions interrelate, how new technologies diffuse, how regional economic activities evolve, how protection of local and regional environments is implemented, and how demographic structure changes. The "qualitative" storyline characteristics include various political, social, cultural, and educational conditions (e.g., type of governance, social structure, and educational level) that often cannot be defined in strictly quantitative terms and do not directly "drive" GHG emissions. These qualitative variables, however, participate in complex "cause-effect" relationships with quantitative emission drivers (for example, economic activities, population levels, energy consumption). Their explicit inclusion in the scenario development process not only makes scenarios more "plausible" and "believable," but also ensures they do not become an arbitrary numeric combination of quantitative parameters" (see Appendix I)

In this Report, the SRES scenarios A2 (high impact) and B2 (medium conditions) are employed to compare with an ideal situation or baseline that it is calculated as non-linear trend of historical values of considered variables. The baseline or Business as Usual (BAU) will never occur, because emissions of GHG's (and their effects) will continue in the future. The reality could be different if the world becomes more aware and actions are taken on mitigation of emissions (B2) or if not (A2).

B. CLIMATE AND TOURISM

Two of the main attractions for tourists in destinations are the beauty of landscapes and a good climate. This is a statement that is widely repeated but not enough studied. Hu and Ritchie (1993) stated the importance of good climate, Shoemaker (1994) prepared a list of destination attributes where he included beauty and environment. Matzakaris (2002) used a bioclimate index regarding tourism and applied it in the Greece Islands. The evolution in the literature on relationships between climate and tourism since the 1970s are referenced by Hamilton and others (2003). They stated some restrictions of the majority of studies such as the possibility of substitution between destinations, the excessive focalization on particular areas or source markets and the sole use of economic variables in detriment of climate forecasts and scenarios. Moore and others (2009, 2010) studied the impacts of variations of a Tourism Climate Index (TCI; see Appendix II) developed by Mieckzowski (1985), on tourism demand in the Caribbean region in comparison with main countries outbound markets.

De Freitas and others (1990, 2001 and 2008) presented a thermal comfort index for tourists (CTI). Main components of the index were the aesthetic, thermal and physical senses, each with its own significance and impact (table 1). These indices include weighted combinations of climate variables such as temperature, precipitations, relative humidity, sunshine hours and wind speed.

It is worth pointing out that an independent impact of climate variables on tourism behavior at destinations is should be taken with caution for two reasons:

a. There is a difference between weather and climate, largely based in considered time (and space) ranges but also in the statistical means by which each of them can be characterized. Weather forecasts and research rest on empirical observations taken in short periods of time within a year´s length of variables such as temperature, rainfall and sea level. It could be daily, monthly or quarterly data, but the main purpose of research is to detect high resolution (i.e. very localized) short term trends in surface and atmospheric conditions and the likelihood of their effects. Climate research, on the other hand, deals with statistical parameters of observed data, like mean, average and standard deviation with the purpose of detecting long term trends of the same variables, usually working with larger regions and decades as the time spam or, as in paleoclimatology, with ranges in the millennia. It is to be born in mind that there is no such thing as mean monthly temperature with respect to GDP as there is no public office that calculates the contribution of such temperature to GDP per capita. Therefore weather as a condition and opportunity to do tourism activities is only presented as a combination of all variables at the same moment; merely the time those activities are taking place. In this case, any study of relationships between tourism and climate must consider the climate variables as a group, hence the use of weighted indices. Nevertheless, those indices, given the time frames considered, are built with climate data, that is, with statistical parameters of observed variable measures, thus identifying long term trends which can be related to corresponding behaviour in the mainstream flow of tourists

Table 1: Climate and impacts 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, 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, longwave radiation, metabolic rate	Thermal comfort, therapeutic, restorative	

Source: De Freitas (2003)

Locally expressed behaviour (i.e. at one specific date and place) is not and should not be the concern of this approach. There is no established way yet to predict exactly how many tourists will arrive to Nassau, Bahamas in any particular day in the future, in the same sense we do not know the expected measures of temperature, rainfall, and wind speed for that day. This is of course, a source of uncertainty.

b. Secondly, weather conditions, and moreover climate trends are related to tourism activities but these cannot be seen as abstractions. Different tourism products should and will work with different arrangements of the same climate variables. Conditions to develop the practice of snow skateboard are obviously far away from those of the sun and sand tourism, but even for sun and sand destinations (as is the case of the Caribbean), beach activities require different conditions that those of golf practicing. Here is where identifying trends also play a distinct role, as stated in the above paragraph, in connection with the mainstream flow of tourists. Thus, if we are looking at a destination whose main product is defined by beach and other coastal resources use activities, trends which affect the set of climate variables as a whole (measured through an index or otherwise) for these activities are to be related with that main flow of tourists, even when distinct and specific minor flows are driven by other conditions. That provides the rationale for the use in this paper of the TCI which was developed precisely for this type of destination.

C. CLIMATE CHANGE AND TOURISM

The World Tourism Organization (UNWTO) and other United Nations Organisations have participated in studies on environmental issues and in definition of topics pertaining to climate change and tourism. The First International Conference on Climate Change and Tourism, held in Djerba, Tunisia, (UNWTO 2003), focused on some central points: (i) to urge all governments to subscribe to agreements on climate change, and (ii) to encourage tourism stakeholders to further support the study and research of the reciprocal implications between tourism and climate change and use more energy-efficient and cleaner technologies and practices, in order to minimize as much as possible their contribution to climate change.

Subsequently the Second International Conference on Climate Change and Tourism, held in Davos, Switzerland (UNWTO 2007), its continued Ministers' meeting of London, 13 November 2007 (UNWTO 2007) and the Ministerial General Assembly (Cartagena de Indias, Colombia, 23-29 November 2007) (UNWTO, 2007) pointed out that climate is not only a risk and impact factor but is a core resource for tourism, specially for sun and sand and winter sports niches. The last mentioned Conference recognized evidence of climate change and its strong relation with tourism. It also stated the need for such a long-term strategy for mitigation which is defined as a decrease in emissions of GHG and the carbon footprint of tourism. Nevertheless, it stated that the tourism sector must not be disadvantaged with respect to other sectors regarding a disproportionate charge particularly on air transport. The Conference expressed the need for giving more attention to Less Developed Countries and Small Island Development States (SIDS) in order to bring them financial, technical and training support to address destinations and entrepreneurs.

Ehmer & Heymann (2008) take into account the influence from climate change on holiday destinations:

- the consequences of the climatic changes, including substitution effects;
- the consequences of regulatory measures to slow climate change and/or to mitigate its negative effects (in particular the increase in the price of mobility);
- the possibilities for adaptation to the changing conditions open to individual regions;
- the economic dependence of tourist destinations on (climate-sensitive) tourism.

UNWTO (2009) states that "four broad pathways by which climate change will affect the global tourism and travel sector": (i) direct climate impacts (depending on length and quality of climate dependent tourism seasons and other damages) (ii) indirect environmental change impacts (loss of attractions like beaches and coastal erosion) (iii) impacts of mitigation policies on tourism mobility (change in patterns of tourists by an increase in transport costs and fostering environmental attitudes) and (iv) indirect societal change impacts (economic costs of adaptation and mitigation in outbound markets will have an impact on its GDP and, consequently, it will have a negative impacts of disposable income for families; on the other hand, it could be an important factor of instability in destinations countries).

The physical impacts of climate change are based on the vulnerabilities[2] of a country. It is recognized that The Bahamas is a highly vulnerable country. Best (2001) and NCCC and Best (2005) argue that vulnerability begins with its geographical and topographical features as a set of low-lying islands with virtually no relief. Vulnerability arises not only for reasons of climate change, but also by damage to the environment that occur for other reasons and human activities such as construction of

[2] Vulnerability is the "ability to manage climate risks without loss of welfare in the long term potentially irreversible." Linked to a high level of risk ("exposure to external dangers over which people have little control"), it reveals the degree of development of a particular area or region, i.e. the capacity transient poor who will face the disasters caused by climatic variations (UNDP, 2007) (Quoted by ECLAC 2009, Climate Change and Development in Latin America and the Caribbean Review. 2009.

buildings and walls on the dunes of the beaches, road construction, over fishing, damage to coral reefs by boats and divers, and others (Sealey, 2003).

Simpson (2008a, 2009) states the main physical impacts include extreme conditions as well as changes and losses in natural heritage and biodiversity. It can also be observed the effects on the availability of natural resources and particularly on water may also be observed.

D. ECONOMIC IMPACTS OF CLIMATE CHANGE ON TOURISM

Studies on the economic impacts of climate change are promoting a great debate in the literature. Since 1992 the problem was faced starting with the UN Conference on Environment and Development (called "Earth Summit"). Pearce and others (1996) established the first procedures to assess economic impacts of climate change using the direct cost method considering the physical impacts of climate change. Roson and Tol (2003:1) pointed out some handicaps: "this method ignores that the impact may change the price (the partial equilibrium effect), that changes in one market may have effects on other markets (the general equilibrium effect), and that climate change may alter investments (the growth effect)". The general equilibrium model was introduced by Nordhaus (1994).

Feenstra and others (1998) did not consider tourism in one of the first handbooks on measuring the economic impact of climate change. But in this century the issue of economics of climate change is strongly being taken into account, as will be apparent. Kemfert and others (2001) used a computable general equilibrium model to determinate the impacts of climate change on the economics of nature, human health, forestry, water resources and energy consumption. The tourism sector was not addressed. Roson and Tol (2003) admit that economic assessments of the impacts of climate change are rare. They used a modified Kemfert's CGE model to comment on the important role of international trade as a measure of economic impacts of climate change.

The Stern Review (2006) constituted a milestone in economic analyses. The importance of this report is to clarify the impacts of climate change as an inevitable phenomenon and its consequences in the case that mitigation could be improved with substantially lower costs. Tol (2006:4) concluded that the Stern Review "can be dismissed as alarmist and incompetent". On the other hand, Nordhaus (2007:34), in agreement with the Review stated: "we need urgent, sharp, and immediate reductions in greenhouse-gas emissions". Furthermore, criticizing the Review, he stated that the report doesn't include any new aspects and Stern used a near-zero time discount rate. He also stated that the issues remain open: "how much, how fast, and how costly". Weitzman (2007) points out that the choice of interest rates remains a matter of debate. He argued whether or not ordinary savings could be able to cover the unknown insurance to buy.

It is necessary to include in this analysis the probability of the existence of great catastrophes, particularly extreme tropical cyclones, which is a very important factor for the Caribbean region. Pielke (2009) explains the correlation between the increase of sea surface temperatures and an increase of intense tropical cyclone activity, based on observational evidence in the North Atlantic since around 1970. Weitzman (2009a, 2009b) works on modeling the economics of catastrophic climate change and proposes the "damages functions" as forms of representation of the improbable, but not impossible economic impacts of extreme events in global warming.

Galindo (2010:4) presents a summary on economy and climate change. Regarding the economic valuation of climate change, he includes two topics. First, the "impact involves the economic vulnerability to climate change and its adaptation processes". And the second one: "the economic impact of the mitigation process". Mitigation and adaptation are processes that represent an important difference for climate change depending on the development level of countries. For instance, the implication of developed countries together with emerging economies (both groups are the main ones responsible for emissions of GHG) is needed regarding effective commitments to mitigate this phenomenon and to cooperate with underdeveloped countries (called "developing") in order to make plans and to fund actions that may contribute to an effort to adapt/modify their less developed economies so that they can face climate change.

It is necessary to agree with Galindo (2010) and ECLAC-IDB (2010) when they stated the characteristics of economic estimates of climate change impacts, because there are lot of differences among studies (regions, sectors and period of time covered, emissions scenarios, the baselines or business as usual scenarios, discount rates used, models) and the different costs (significance, positive and negative impacts in short or long term, non-linear and irreversible, dependence on climate scenarios).

These considerations imply the difficulty in assessing the real economic impacts of climate change on tourism. It could be considered also that the Fourth Assessment Report of IPCC does not include tourism. Nevertheless, in the IPCC (2010) "Agreed Reference Material for the IPCC Fifth Assessment Report" the proposal to study the economic impacts of climate change on the tourism sector is present. Although the theoretical validity of the approach taken in this report will be further discussed in the methodological section, it is important to signify here that many studies, when dealing with tourism destinations use a complex systems approach and many destinations are shown to behave as complex adaptive systems (Farrel and Twining-Ward, 2004; Faulkner and Russel, 1997). This is crucial in defining the modeling methods and techniques employed, mainly due to the change in many of the underlying theoretical assumptions.

It is important to note in the existence of a great deal of uncertainty in the projection of economic impacts of climate change variables. Uncertainty in climate variables in connection with arrivals was addressed above when clarifying the relationship between climate and tourism, but this theme will be further addressed throughout this report. Suffice it to say that there's little precision in the projection of structural economic variables across scenarios, which is in turn made more complex by the very nature and scale of the systems, the time and the space ranges considered. Specific data availability leads to the unavoidable use of proxies, adding further noise to the projections.

Finally, it is important to notice that tourism is a tertiary economic activity. The absence of studies assessing economic impacts of climate change on primary and secondary sectors such as agriculture and energy as well as on non-market goods like wetlands and coral reefs in a country or region, limit the projections on transferred costs and also the demarcation of mitigation and adaptation measures in a clearer, downscaled and economically sounder context. Also, economic studies on transfer risks (as CCRIF-ECA study) are not available for The Bahamas. This paper presented also a restriction regarding the 25 km grid of PRECIS RCM that implies values of climate variables on sea instead of land surface.

III. ANALYSING CLIMATE CHANGE IN THE BAHAMIAN TOURISM SECTOR

A. ANTHROPOGENIC EFFECTS IN RELATION TO TOURISM SECTOR

Emissions of GHG from the Caribbean, as a whole (including all sectors) are only 1 % of global emissions (Simpson and others, 2008a). Any mitigation action could have more influence in terms of "best practices" to countries that emit high levels of GHG rather than to diminish GHG emissions. Nevertheless, the Caribbean is one of the most highly condensed regions in terms of energy-intense use if calculated on a per visitor basis as a result of the need to use cruise vessels or aviation planes to reach them.

Any action towards mitigation that considers taxing flights in the United States of America or in any other main outbound market country to the Bahamas will generate an important negative impact in numbers of arrivals to the country. A rise in oil prices could also contribute to this effect. In relative terms, the Bahamas is one of the major emitters in Latin America and the Caribbean.

Table 2: Total GHG emissions for The Bahamas

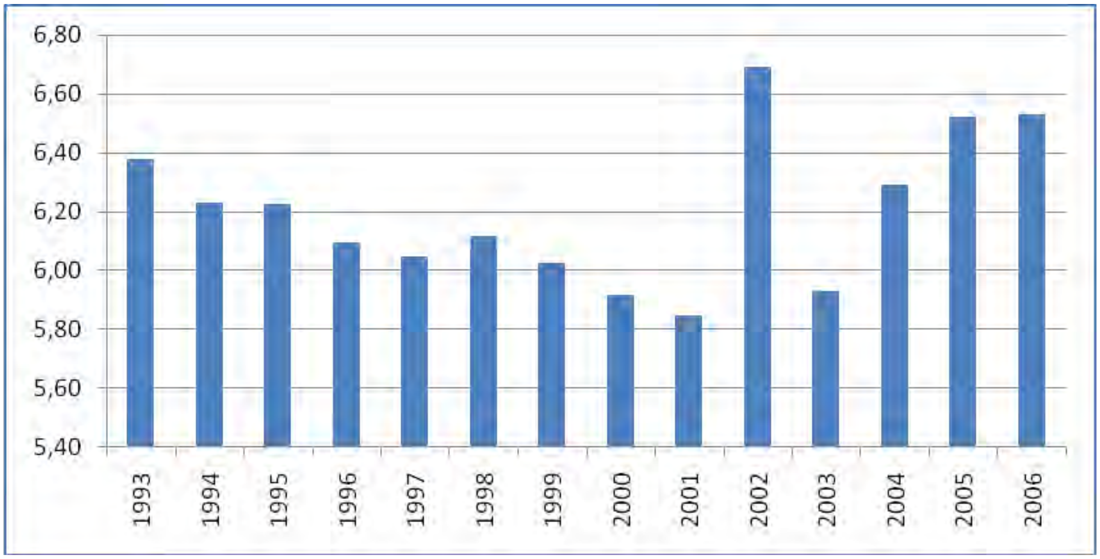
Years	Million Metric Tons CO_2	Rank	% of World Total	Metric Tons CO2 per person	Rank
Cum 1990-2006	31.5	135	0,01%	97,5	53
2000	2.3	159	0,01%	7.2	74
2001	1.8	137	0,01%	5.8	53
2002	2.1	135	0,01%	6.7	44
2003	1.9	138	0,01%	5.9	55
2004	2.0	137	0,01%	6.3	50
2005	2.1	138	0,01%	6.5	48
2006	2.1	138	0,01%	6.5	49
Average 2000-06	2.0			6.4	
Average 1990-06	..			5.7	

Source: Climate Analysis Indicators Tool (CAIT) Version 7.0. (Washington, DC: World Resources Institute, 2010).

These figures do not include the main important source of emissions, which are the consumption of oil derivatives to transport visitors to the islands. This is because the emission is measured at departure site (both for ships and planes). The Bahamas stated per capita emission mean of CO_2 is 6 tons, well above the world mean of 4.3 (table 2 and figure 1)). The Bahamas ranks high in this index, second only to Trinidad & Tobago in all of Latin America and the Caribbean if calculations are made in relation to general population.

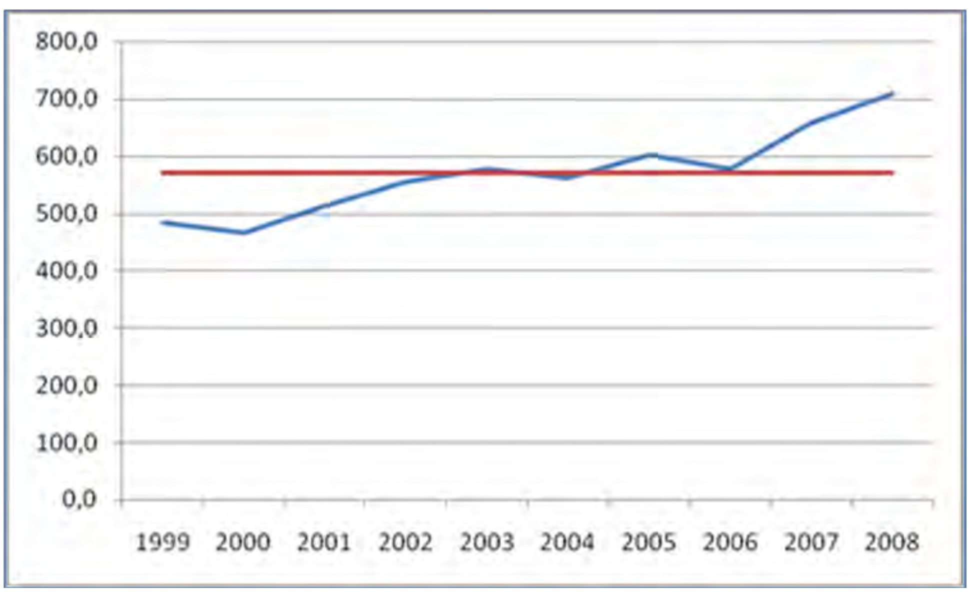
The majority of tourists that access the Bahamas arrive by air transport which is a main contributor to GHG emissions. A way to approximate efficiency is using an estimate index of electrical consumption of tourists, called TEC (Tourist Electrical Consumption), as a proxy for unavailable data of real electrical consumption of tourists. This index is calculated dividing total MW/h of electricity consumed by commerce & industrial sector plus the street lighting between total stopover arrivals. Figure 2 shows the increasing trend of the index. The mean value for these years is 570 KWh (red line).

Figure 1: Carbon Footprint by per capita basis 1993 – 2006



Source: Caribsave/CCCCC/UOxford (2009) and
CTO (2007) Selected statistical indicators of Caribbean countries. Vol. XXI

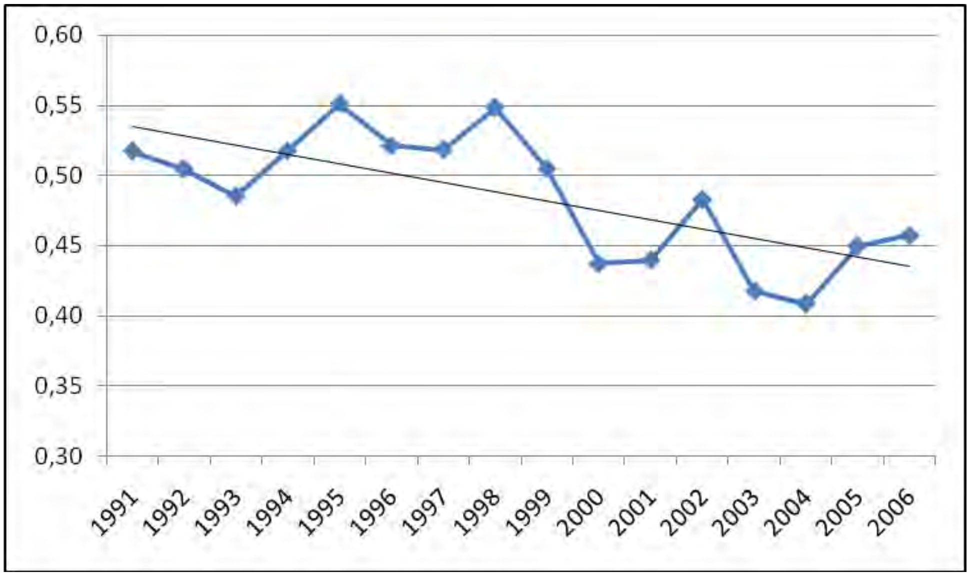
Figure 2: TEC (Tourist electrical consumption) 1999 – 2008



Source: Elaborated from The Central Bank of The Bahamas Quarterly.

In a similar manner, a carbon footprint index for tourism (TCF) may be determined. In this sense, arrivals measure total visitors (stopovers and cruise passengers). The trend in the index, as is shown in Figure 3, is declining from 0.52 ton CO_2 emission per visitor to 0.46 ton.

Figure 3: Tourist Carbon Footprint 1991 – 2006



Source: CO_2 emissions: UN Statistical Division (Website: http://data.un.org)

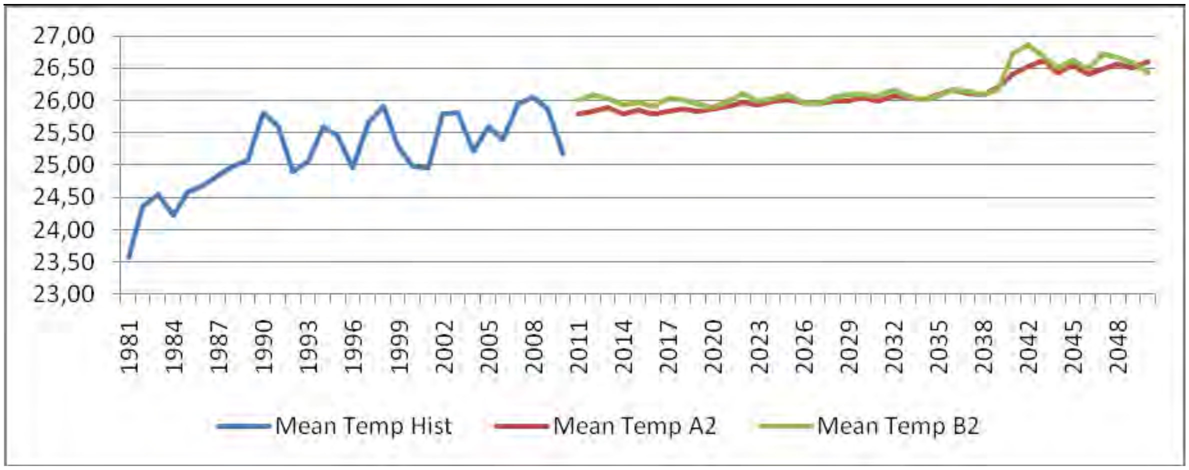
B. CLIMATE VARIABLES

An analysis of climate variables in the context of The Bahamas is addressed in this section. First of all, it is necessary to say that the country enjoys a privileged position between northern 24 and 27 parallels, and it is precisely in the middle of the flow of warm waters (a true river in the ocean) known as the Gulf Stream. These conditions provide warm winters and moderate to strong summers, even when most of the important inhabited islands are above the geographical tropical zone and properly in the North Atlantic. Nonetheless, The Bahamas has been traditionally reckoned as belonging to the Caribbean community of nations, for a variety of reasons, among which climate is no less important.

1. Temperature and Precipitation

Mean temperature has been increasingly rising in The Bahamas land and sea area. This is entirely consistent with both global and regional observations, as can be seen in Simpson and others (2009). Rising temperatures are expected to reach the 1.5 °C mark by 2050 in SRES A2 scenario. Projected values of local minima are at any rate expected to increase by at least by 1 °C in the best case scenario. Nonetheless, it is to be borne in mind that locally intensifying phenomena, as ocean acidification, which are likely to affect coastal lowlands in countries like The Bahamas, might even cause increases in temperature of up to 3 °C at some places. Figure 4 depicts the historical values for mean temperature and projections into B2 and A2 SRES scenarios.

Figure 4: Mean temperature variations: historical and projected



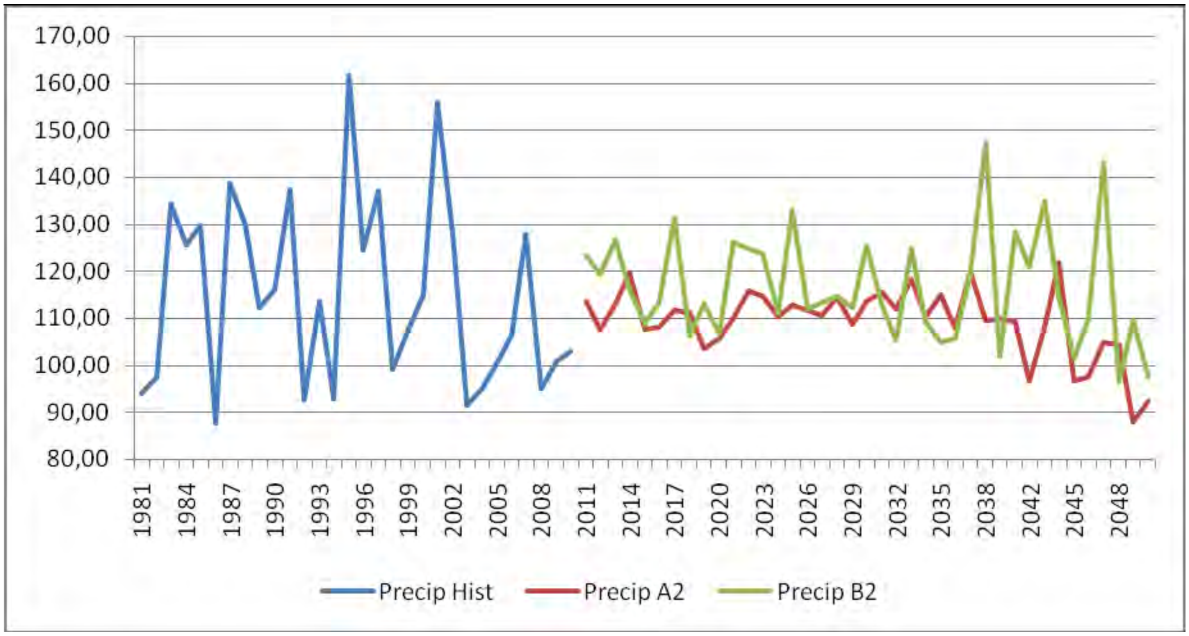
Source: Elaborated with data from Bahamas Department of Meteorology and PRECIS (RCM)

Rainfall has a locally distinct behaviour. In effect, mean precipitation is expected to decrease global and regionally, but as remarked by Simpson and others (2009), an area comprising The Bahamas is projected to have some horizontal pattern regarding precipitation measures for this century. This is believed to be caused by excess rainfall accompanying tropical cyclone phenomena, although reasons behind this remain largely unclear. Figure 5 shows observed and expected values for SRES A2 and B2 scenarios.

2. Sunshine hours, Wind speed and Relative humidity

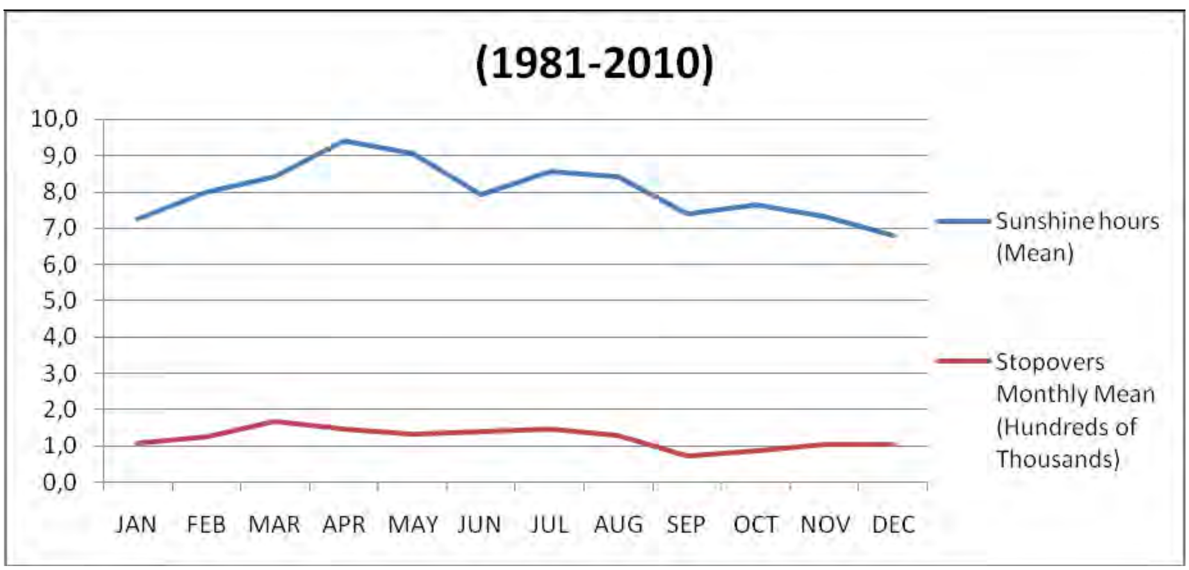
Most of the tourism activities in sun and sand destinations are done during daily time. Moreover, many of them like sunbath, beach bath, scuba, snorkeling and diving require sunshine for the experience to be qualified as pleasant by customers. It is in this sense that the number of sunshine hours, as a measure of total daily time in which the sun shines (i.e. not cloudy o partly cloudy), comes to play a role while considering relationships between climate and tourism variables. However, a look to modeled data from PRECIS RCM showed no significant differences between SRES A2 and B2 in this particular variable. Mean sunshine hours are presented in Figure 16 throughout the year for the period 1981-2050. It is important to notice the slightly similar behavior of seasonal observed stopovers arrivals (figure 6).

Figure 5: Mean monthly precipitation variations: historical and projected*.



* Note: Data up to 2010 is historical data. Data is in mm.
Source: Elaborated with data from Bahamas Department of Meteorology and PRECIS (RCM)

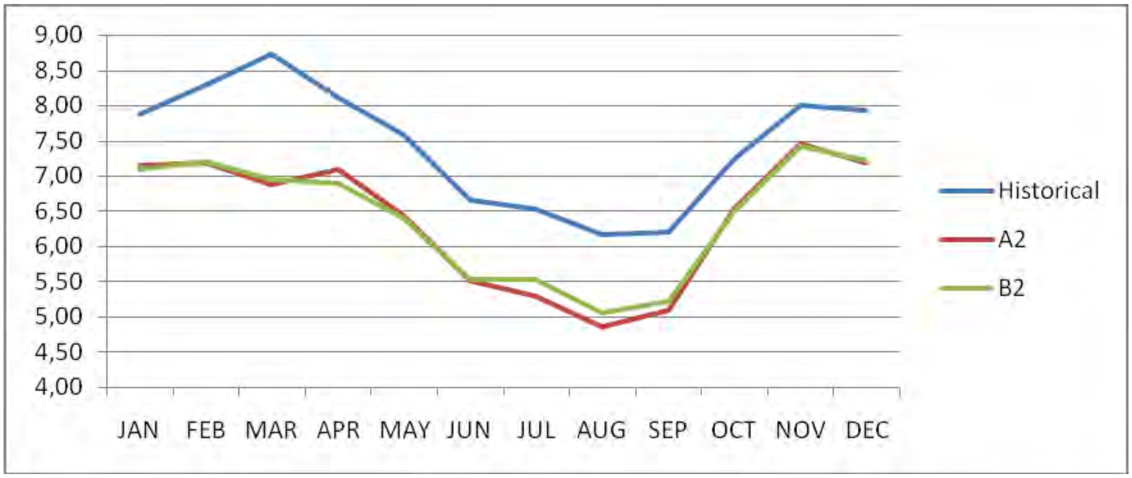
Figure 6: Mean monthly sunshine hours & Seasonal Stopovers mean. (1981-2010)



Source: Elaborated with data from Bahamas Department of Meteorology and PRECIS (RCM)

Wind speed is another important factor when relating climate variables to tourism demand behavior. Effectively, as stated by Moore (2010:7), winds might have a "variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while wind chill in cold climates rated negatively)". In the case of The Bahamas, wind speeds are usually a measure of temperature dissipation, due to the almost stable hot climate, and thus are usually taken as a positive influence on tourists overall satisfaction. This is of course the case with average wind speed (once again the difference between climate and weather), not to be confused with particularly dangerous situations that surround hurricane events, in which wind gusts reach sustained high marks for a short period. Wind speeds are expected to behave as shown Figure 7.

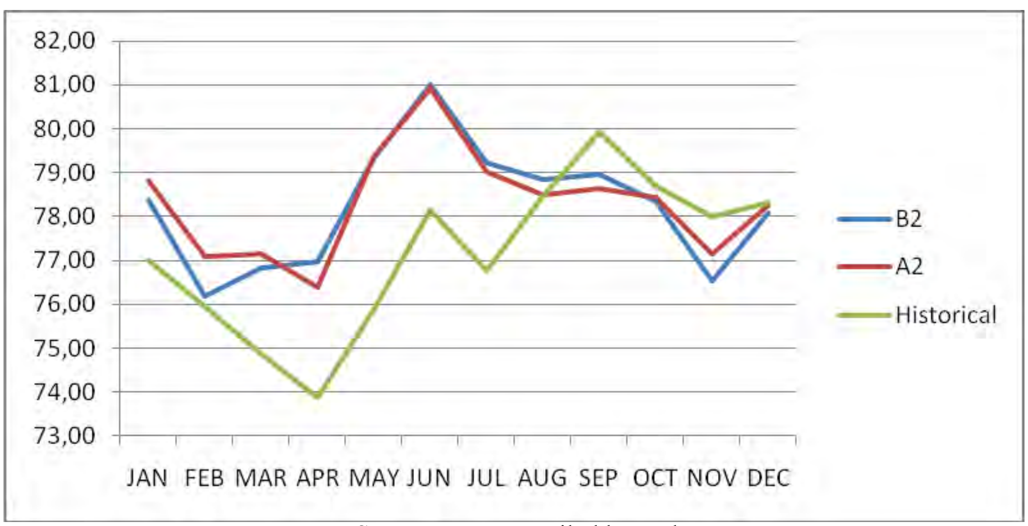
Figure 7: Average wind speeds. Historical and PRECIS RCM SRES modeled data



Source: Data compiled by author

Closely connected with thermal comfort and particularly with temperature, relative humidity is a significant differentiating factor when one takes temperature into account for a pleasant experience. In effect, even hot temperatures are bearable at low values of relative humidity, while the converse is not the case. High relative humidity distorts even otherwise fairly pleasant conditions. Figure 8 shows the distinct behavior of relative humidity at both SRES scenarios.

Figure 8: Relative Humidity. Historical and PRECIS RCM SRES modeled data.



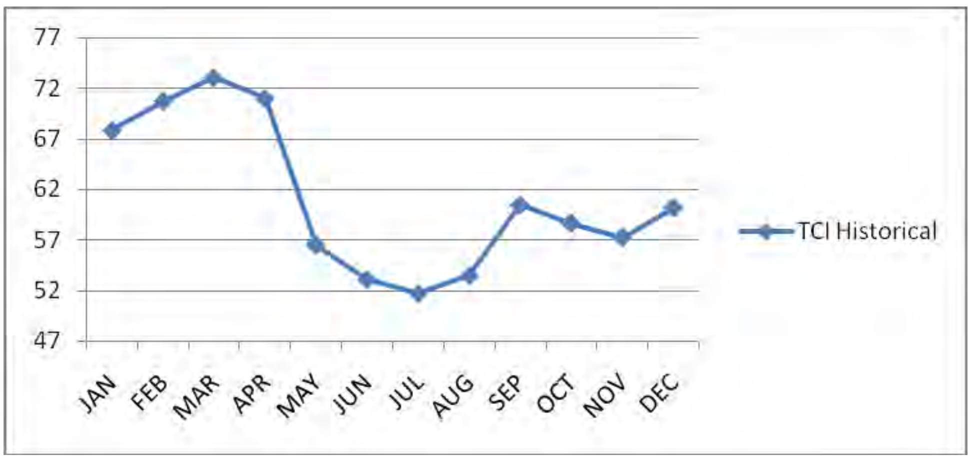
Source: Data compiled by author

3. Tourism Climate Index

As stated above, analyzing relationships between individual climate variables and tourism behavior is often a meaningless exercise. Therefore, a composite index of climate variables related to tourist satisfaction is calculated, the Tourism Climate Index, addressed in Section II and detailed in Appendix II, so as to provide an integrated assessment of the change in the set of climate variables and to investigate the underlying relationship with tourism demand.

According to our own calculations the historical TCI for The Bahamas is above 70 from February to April and declines rapidly after this period (figure 9). During these months, The Bahamas is ranked highest in terms of its TCI relative to other Caribbean island states (Moore and others, 2009). However, between June and September TCI ranking goes down to last among the 20 Caribbean islands: during these months the TCIs falls to just below 50, the demarcation between a marginal and unfavorable destination in terms of climate. The main reason behind this significant deterioration is the daytime comfort index, which falls from around 3 during the January to May months to as low as 1 in August.

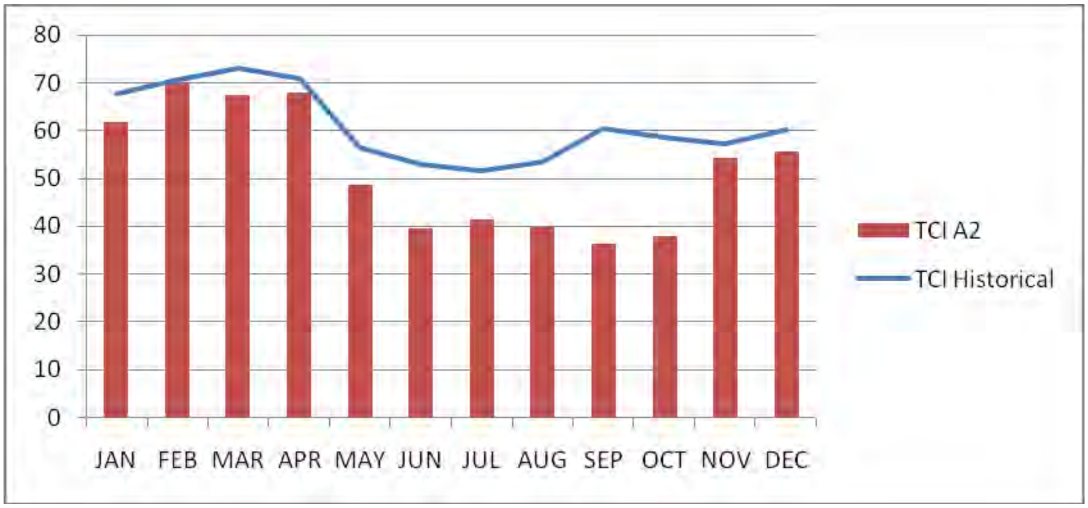
Figure 9: Tourism Climate Index for The Bahamas (1981-2010)



Source: Data from Department of Meteorology, Bahamas and PRECIS RCM

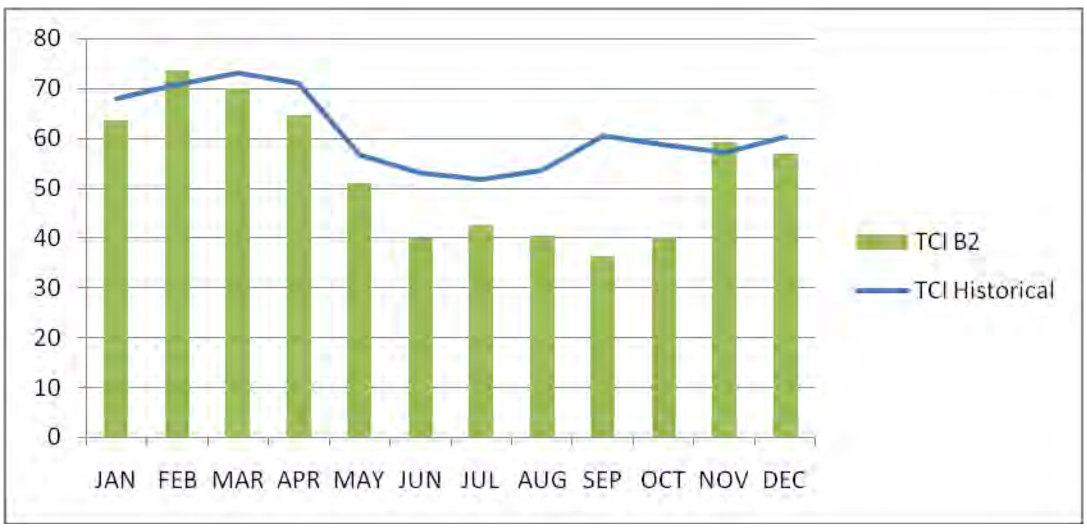
The calculations of the TCI from SRES B2 and A2, shown that the situation formerly expressed is going to worsen. Effectively, from figures 10 and 11 it can be readily seen that the index goes to considerably lower values, making the TCI qualifications degrade as well.

Figure 10: TCI comparison between historical and SRES A2 scenario



Source: Data from Department of Meteorology, Bahamas and PRECIS RCM

Figure 11: TCI comparison between historical and SRES B2 scenario



Source: Data from Department of Meteorology, Bahamas and PRECIS RCM

Figures 12 (a), (b) and (c) make a comparison between the TCI for The Bahamas and those from North America. The graphics show how there is a lesser gap between favourable climate conditions for travelling to Bahamas from North America and those to travel inside the continent, because at the same time the North America's TCI improves, making domestic travel more desirable, in concordance with Hamilton and others (2003).

Figure 12: (a) Historical TCI

Figure 12 (b): TCI for the B2 scenario

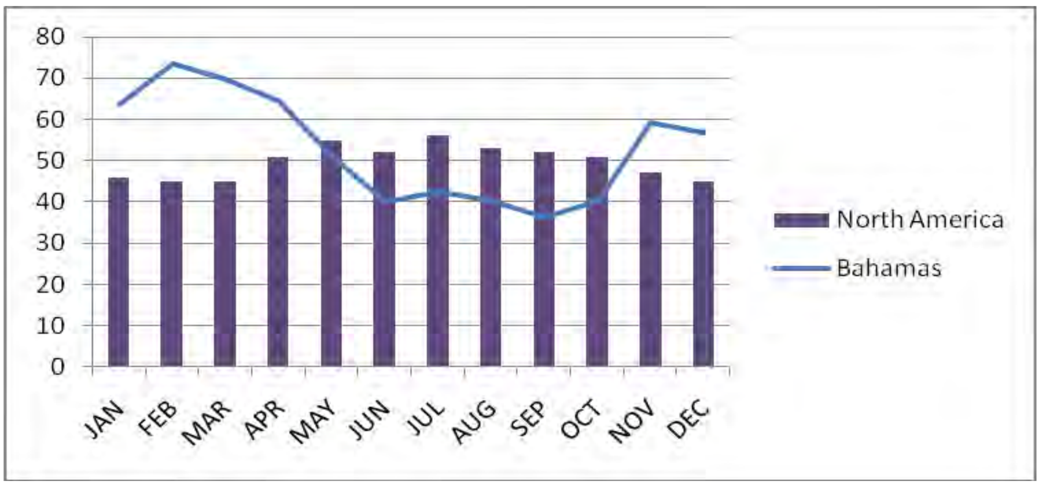
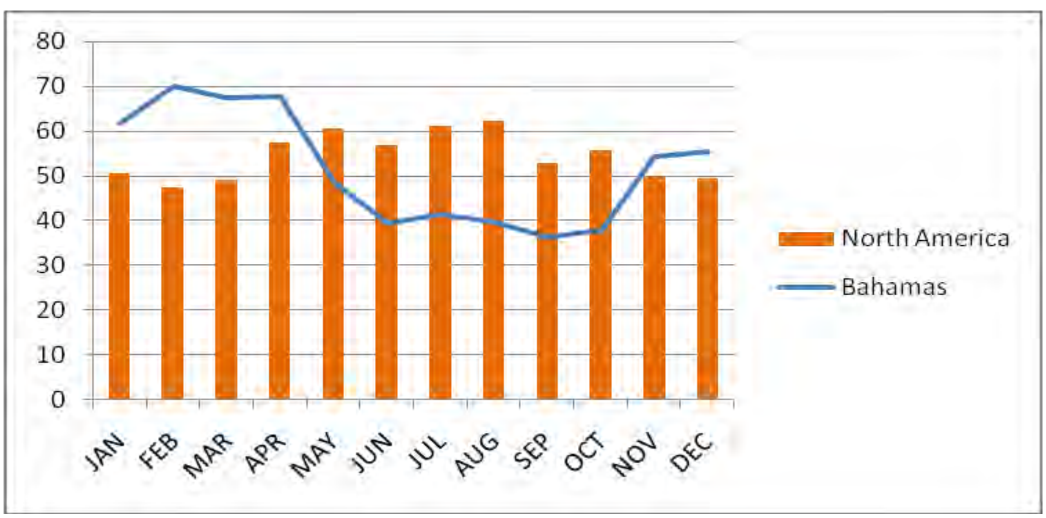


Figure 12 (c): TCI for the B2 scenario



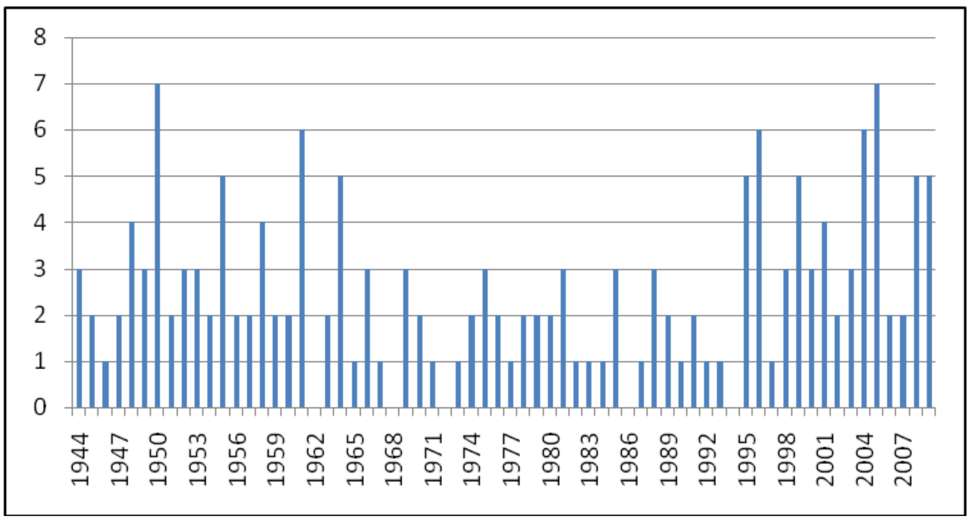
Source: Data from Department of Meteorology, Bahamas, PRECIS RCM and Moore and others. (2009)

4. Extreme Events, Sea level rise and coral reefs - Physical Impacts

The physical impacts of climate change are based on the vulnerabilities[3] of a country. It is recognized that The Bahamas is a State of high vulnerability. BEST (2001) and NCCC & BEST (2005) argue that vulnerability begins with its geographical and topographical features as a set of low-lying islands with virtually no relief. The vulnerability arises not only for reasons of climate change, but also by damage to the environment that occurs for other reasons and human activities such as construction of buildings and walls on the dunes of the beaches, road construction, over fishing, damage to coral reefs by boats and divers, and others (Sealey 2003).

Simpson (2008, 2009) states that the main physical impacts include extreme conditions, changes and losses in natural heritage and biodiversity. The effects on the availability of natural resources and particularly on water and direct impacts of combined effects of sea level rise and tropical cyclones through damages and destruction of infrastructure can also be observed. One of the extreme events that has hit The Bahamas most frequently in the last few years is intense tropical cyclones. This does not mean that the islands have not suffered a much higher number of storms not classified as "extremes", as is shown in Figure 13.

Figure 13: Annual number of tropical cyclones in The Bahamas (1944-2009)



Source: KNMI Climate Explorer (Landsea – NOAA)

Figure 14 shows The Bahamas has suffered an average of 2.6 tropical cyclones annually. Data for tropical cyclones (TC) was obtained from Dr. Landsea's (of the National Hurricane Center, adscript to U.S. National Oceanic and Atmospheric Administration) database for North Atlantic tropical cyclones, through the Climate Explorer of the Kingdom of The Netherlands Meteorological Institute (KNMI) and filtered through the geographical coordinates of Bahamas. It is to be borne in mind that tropical cyclones is the generic name for tropical storms, and do not carry the same meaning as hurricanes, for example. Tropical cyclones include full Saffir-Simpson hurricanes scale, but also tropical storms and depressions.

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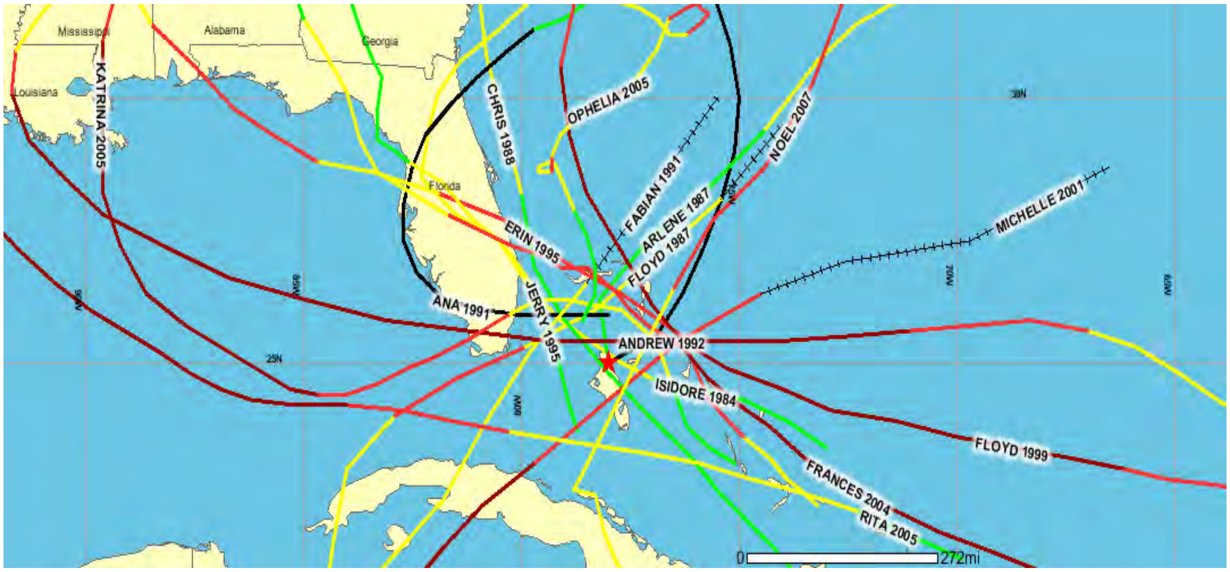
[3] Vulnerability is the "ability to manage climate risks without loss of welfare in the long term potentially irreversible." Linked to a high level of risk ("exposure to external dangers over which people have little control"), it reveals the degree of development of a particular area or region, i.e. the capacity transient poor who will face the disasters caused by climatic variations (UNDP, 2007) (Quoted by ECLAC 2009, Climate Change and Development in Latin America and the Caribbean Review. 2009.

Therefore, not every TC results in an extreme event, as it can be easily mistaken, and some have even proven beneficial, especially in the dry season. For example, taking into account the last 30 years and analyzing the available data it can be seen that even though there were tropical cyclones in the period between 1979 and 1983 there were no extreme events. The most relevant tropical cyclones are shown in Figure 15.

Figure 14: Most important tropical cyclones that have hit The Bahamas



Source: U.S.NOAA Generated at http://csc-s-maps-q.csc.noaa.gov/servlet/

The data of these events are shown in Table 3:

Table 3: Tropical Cyclones – The Bahamas 1984 – 2007

Year	Name	Impact	Costs (current) („000 $)	Death	Cat.
1984	Isidore	Familiy Islands	750	0	TS
1987	Arlene	Andros	0	0	TD
1987	Floyd	GB	0	1	TD
1988	Chris	FI. And GB	0	0	TS
1991	Ana	Bimini	0	0	TD
1991	Fabian	GB	0	0	TS (EX)
1992	Andrew	All	250000	3(1)	H5
1995	Erin	All	400	0	H1
1995	Jerry	GB and Bimini	0	0	TD
1999	Floyd	All	450000	1	H4
1999	Dennis	GB and FI	0	0	H1
2001	Michelle	All	0	0	H1
2004	Frances	All	600000	2	H4
2004	Jeanne	GB and FI	955000	7	H3
2005	Wilma	GB	100000	1	H1
2007	Noel	NP and FI	0	1	TS

Source: EMDAT & NOAA

Other statistics specify interesting data in relation to these cyclones, such as the natural disasters summary is provided by UN ISDR (see table 4).

Table 4: Natural Disasters from 1988 – 2008

No of events:	13
No of people killed:	19
Average killed per year:	1
No of people affected:	22,200
Average affected per year:	1,057
Ecomomic Damage (US$ X 1,000):	2,550,400
Ecomomic Damage per year (US$ X 1,000):	121,448

Source: UN-ISDR http://www.preventionweb.net/english/countries/statistics/?cid=12

The paucity of data on the economic costs and damage of these events should be noted. For example, there are a number of category 1 hurricanes making landfall that do not have any associated cost. Sealey (2003) points out that the 1999 hurricanes caused great devastation in the coastline. The report further states that the erosion and bleaching equivalent to a century's worth happened in just one day. On the other hand, an underestimation can be noted in other cases, like for example, in 2004 TC, Zapata (2004) declared that The Bahamas lost 10 % of its GDP in damage and destruction of assets (productive, service and personal). This does not include the equally important damage to people (including deaths), to the environment and the ecology of the country. It is definitely an issue that remains quantified with less precision than the more visible physical damages.

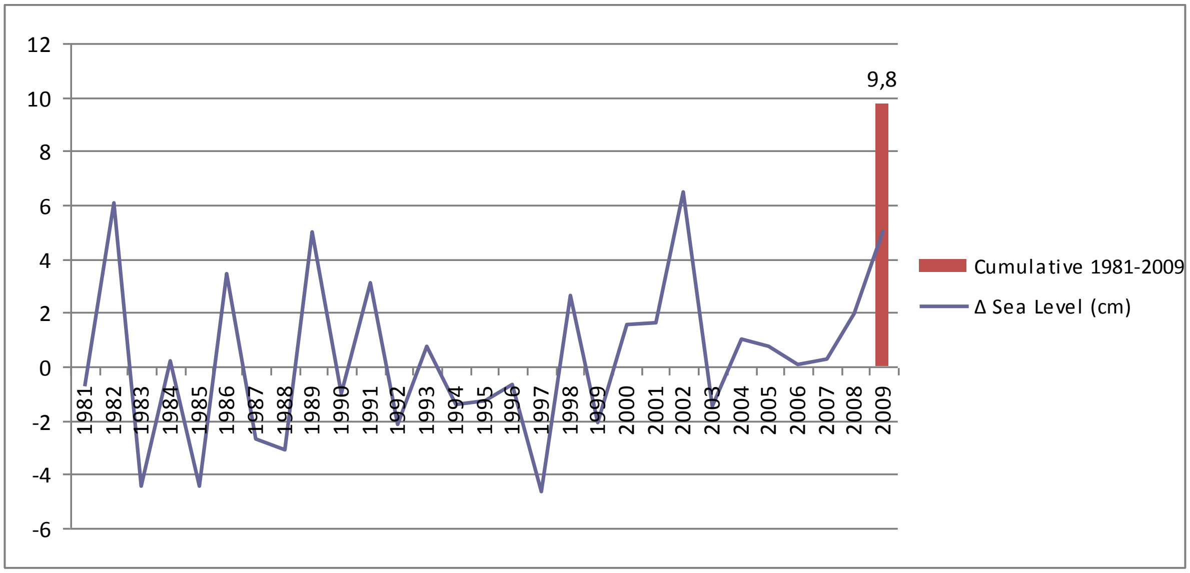
On the other hand it is the issues of effects of extreme events on biodiversity also need to be addressed. ECLAC (1999) cites an example of coral bleaching on Great Bahama Black in 1963 and a destruction of corals in New Providence as a consequence of Hurricane Betsy in 1965.
The presence of tropical cyclones significantly increases the danger to biodiversity, while accompanied by strong winds (which ever it will be more, according to projections globally accepted) and upwelling from the sea. Gardner and others (2005) stated a general reduction in coral reefs of 17% on average in the year following a hurricane impact.

Moreover, the main hazard that hangs over the availability of water resources in The Bahamas is over-exploitation of aquifers. This leads to saltwater intrusion of aquifers. A similar (but sudden) effect is produced by both the storm surges of the sea, were tropical cyclones to occur, and the decrease in rainfall. The major direct losses (damage and destruction of infrastructure) are associated with the occurrence of tropical cyclones, especially the higher category. The loss of human life, as stated, spreading diseases and other health impacts, from one side, and loss of attractions and infrastructure from the other, are the major physical impacts of climate change in terms of increasingly dangerous tropical cyclones.

5. Sea Level Rise

The Bahamas has been exposed to rising sea levels for the last 4 000 years, since the retreat of the last glacier. In this period sea level rise rates are about 0.4 mm/year, although in the last century an increase was observed in the range of 1.0-2.5 mms/year (Sealey, 2003). This is in fact not much below the projected rate of 4.0 mm/year. Current measurements indicate a sea level rise average of 3. 3 mm per year over the last sixteen years (figure 15), which in turn represents a further 32% increase from records by Godfrey and others (2003).

Figure 15: Sea level historical annual cumulative observations

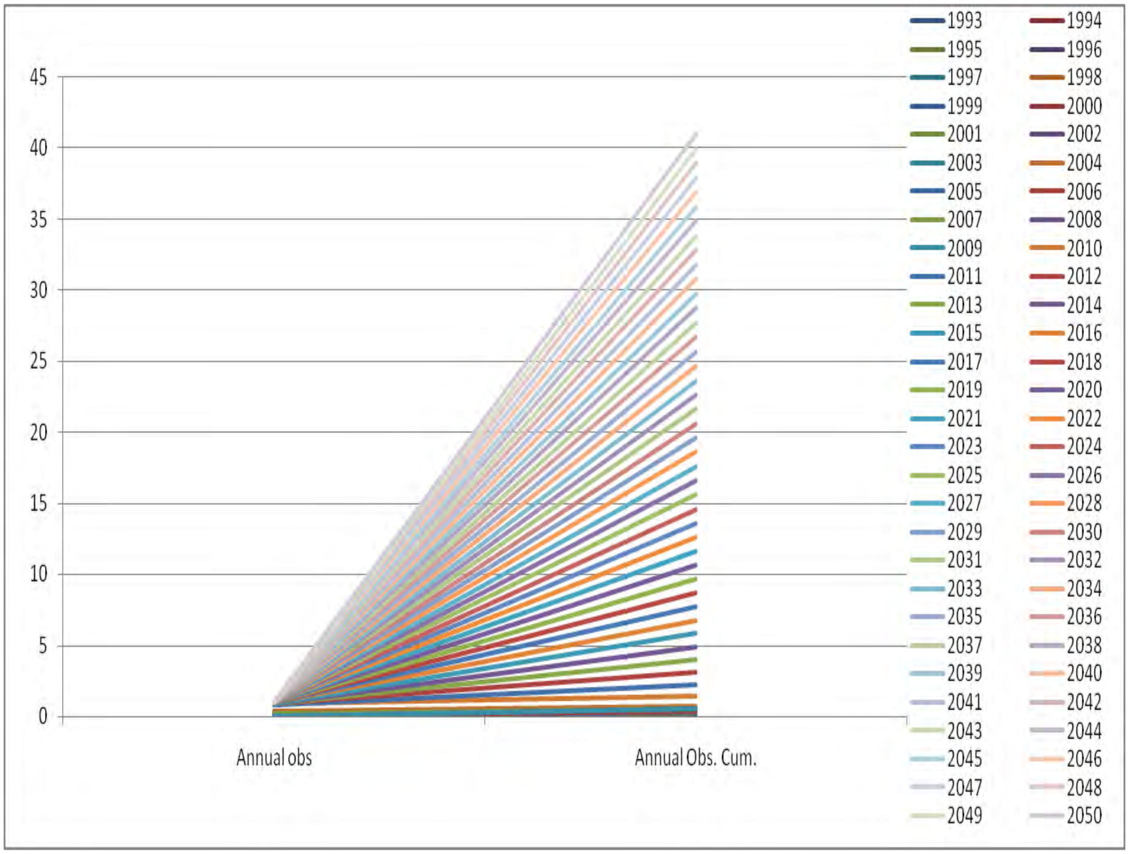


Source: Permanent Service of Mean Sea Level. University of Colorado at Boulder.

Sea level indices were gathered from satellite altimetry and tidal gauge data obtained from University of Colorado at Boulder through the Permanent Service for Mean Sea Level. Mean sea level variation is computed from data for each available year, measuring the annual mean of cumulative observations differences in cm. The projections made in this paper from observed data indicate a sustained increase, suggesting a 40+ cm mark to be reached at 2050. This would follow a mean increase variation of 0.9 cm per year. Nevertheless, it is important to point out that this projection is not as accurate as those made taking into account many inputs that are related with the phenomenon. Ice shelf melting for example, an issue now been considered by science, is not put into the equation here, a fact that makes this projection highly conservative. In this regard, comparisons, although useful to obtain an insight into several approaches to the issue, are to be taken with caution. In order to make sense out of physical projections of impacts and sea level rise, annual cumulative projections should be scaled to account of an increasing mean variation which roughly follows Grinsted and others (2009), by taking into account ice melting in the ice shelves (Greenland and Western Antarctica). Figure 16 shows the cumulative results from the projection made in this paper in sea level rise.

On the subject of physical impacts of SLR, regarding biodiversity it can be said that mangroves are important reservoirs of marine life in the Bahamas and wetlands will be affected by rising sea levels of either 0.5 or 1 m. Simpson and others (2009) estimated that 15% of wetlands in this country will be affected if the sea rises by 1 m. The characteristic of low-lying coastal archipelago of the Bahamas suggests that mangroves will be negatively impacted with even small increases in sea level. Sealey (2003) notes the lack of studies on the impact of climate change on sandy bottoms, whether grass beds or algal plains.

Figure 16: Projected cumulative sea level rise for the period 2011-2050



Source: Projections of SLR obseved data in cm.

The freshwater supply for populations and visitors is obtained from the accumulation of rainwater in shallow underground deposits. These aquifers are located in the upper surface of saline water (Simpson and others, 2009). The country is completely dependent on these water tanks. Since there are deposits in some and not in all the islands, water is a scarce resource that is distributed by barge. Climate change, as stated, can increase the risk of sea level rising and, hence, salt contamination of natural deposits of fresh water is the main risk posed by SLR to water resources in The Bahamas. Simpson and others (2009) presents a table for impacts of rising sea level in The Bahamas, the second main hazard (table 5).

Table 5: Main impacts of sea level rise in The Bahamas.

The Bahamas	1 m SLR	2 m SLR	3 m SLR	4 m SLR	5 m SLR	6 m SLR
Land Area	10%	17%	30%	50%	68%	81%
Population (2010 est.)	5%	8%	12%	19%	29%	42%
Urban Area	3%	7%	13%	23%	33%	44%
Wetland Area	15%	23%	41%	65%	78%	84%
Agricultural Land	3%	7%	14%	34%	38%	51%
Crop and Plantation Land	2%	6%	11%	21%	36%	53%
Major Tourism Resorts**	9%	11%	24%	26%	35%	50%
Airports	13%	25%	38%	69%	81%	91%
Road Network	2%	6%	11%	19%	30%	43%
GDP (2008 est.)	4%	8%	12%	19%	29%	42%

** Please note that these are "major" tourism resorts, and not ALL tourism resorts.

Source: Simpson and others (2009)

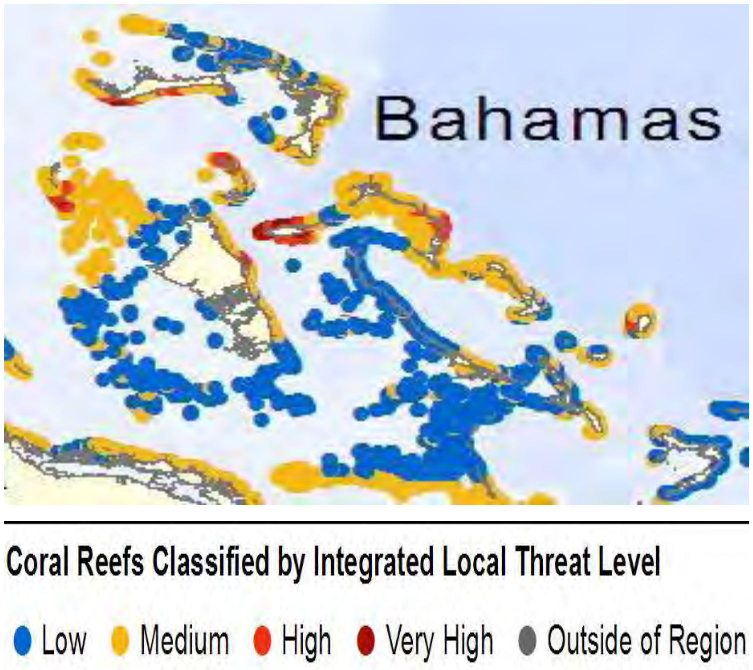
Bas and others, (2008) suggest that sea level rise, tropical cyclones and storm surge have led to losses in millions. It is expected a loss of land that can reach nearly 10% of the nation surface. A rise in sea level would cause erosion of beaches and coasts and, since most hotels are located along the coast, this erosion could have a direct impact on these structures. The loss of airports is another climate change impacts, since many are too close to the coastline. Bahamas has 55 airports of different sizes (The Outer Islands of The Bahamas 2010, Airport Guide). A balance of losses by sea level rise suggests that, if the sea rises 1 m. at least seven airports would be lost.

6. Coral Reefs

Coral reefs are a wealth of biological diversity and tourism in the Bahamas. It represents 5% of all coral reefs in the world (Bahamas Guide 2010a). BEST (2001) states that coral reefs play an important role as natural barriers to storm surges caused by tropical cyclones and now are suffering from over-exploitation, pollution and unsustainable practices related to tourism. Simpson and others (2009) includes the problem of ocean acidification as a negative impact on coral reefs.

More recently, the World Resources Institute, based at Washington, published a study entitled "Reefs at Risk: Evaluation" (WRI, 2011). The study analyzed the Caribbean area, evaluating how endangered coral reefs were by local threats (overfishing, unregulated and tourism use). The report also estimated levels of risk for the same coral reefs if today´s patterns of use should continue up to the year 2050. As it can be seen in the image (Figure 17), the most threatened coral reefs areas for The Bahamas are those present in the outstanding tourism destinations of the country, surrounding the islands of Grand Bahama, New Providence, Paradise Island and Eleuthera.

Figure 17: Risk assessment for coral reefs in The Bahamas to 2050.



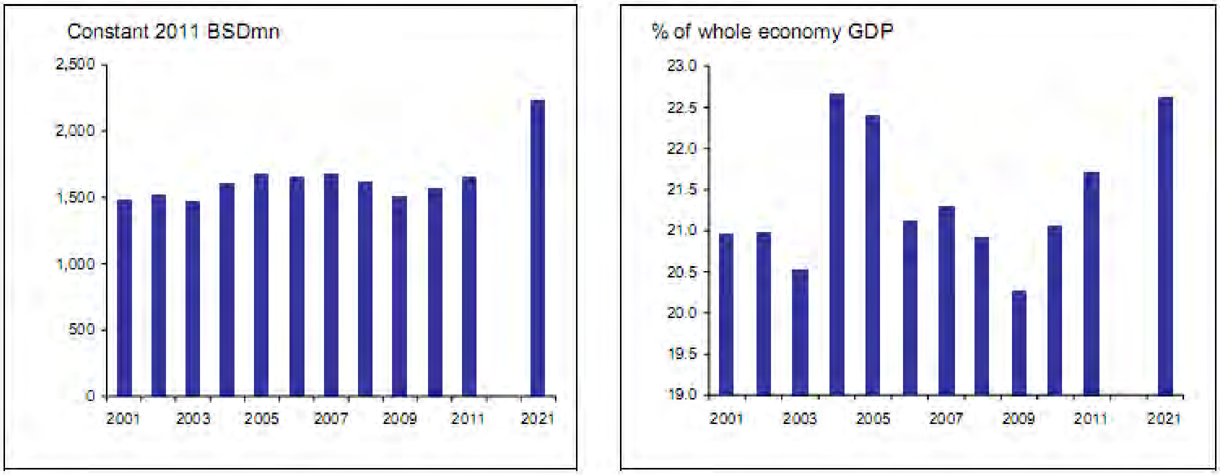
Source: Reefs at Risk: Evaluation. WRI, 2011.

C. TOURISM IN THE BAHAMAS ARCHIPELAGO

The Commonwealth of The Bahamas is an archipelago composed by 700 islands (29 are the most important) and more than 2300 little cays and rocks islets, with a total surface area of 13,939 square kilometers. The islands are low-lying and are located north of Cuba and east of Florida Peninsula in the Atlantic Ocean. Badie & Vidal (2009) estimate a population of 338,000 inhabitants (24.3 inhabitants/km^2). Ninety percent of the population lives in just three of the islands: New Providence, Grand Bahama and Abaco.

The main livelihood sectors of the Bahamian economy are trade and tourism. WTTC (2005, 2010) and WTTC (2011) indicated that in the near future, the Bahamian economy's dependence on tourism could be extended, because of the participation of Tourism and Travel Economy in Gross Domestic Product (GDP). In terms of Tourism Satellite Account following WTTC (2011) "The direct contribution of Travel and Tourism to Gross Domestic Product is expected to be BSD 1,648.4 mn (21.7% of total GDP) in 2011, rising by 3.1% to BSD 2,226.2 mn (22.6%) in 2021 (in constant 2011 prices)" (figure 18).

Figure 18: Direct Contribution of Travel and Tourism to GDP



Source: World Travel & Tourism Council WTTC (2011)

Within the sector, total visitor arrivals[4] grew with an average annual rate of 3.7 %, between 1981 and 2009 (figure 19). In the years 2004 - 2008 arrivals had a steady decline until the beginning 2009. It was caused mainly by the influence of the international crisis and higher prices of almost all tourist services in the country.

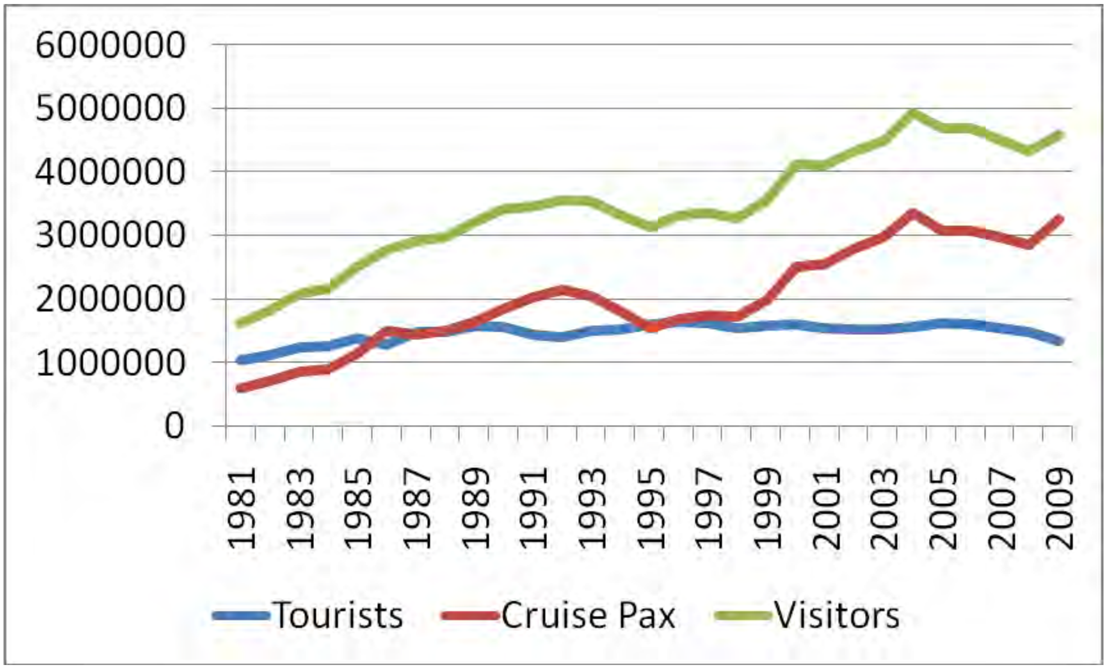
Table 6: Stopovers Arrivals 2006-2009

2006	1.600,112
2007	1,527,726
2008	1,462,758
2009	1,326,722

Source: The Central Bank of The Bahamas (Quarterly Statistical Digest) from 2006-2011

[4] As is common in tourist literature, World Tourism Organization and United Nations Statistics, visitor arrivals comprises tourist arrivals or stopover arrivals and excursionist arrivals, mainly cruises arrivals, depending on if the passenger pass one night or more (tourist) or if they don't use destination lodgings (as in cruises).

Figure 19: Visitor arrivals to The Bahamas 1981 – 2009



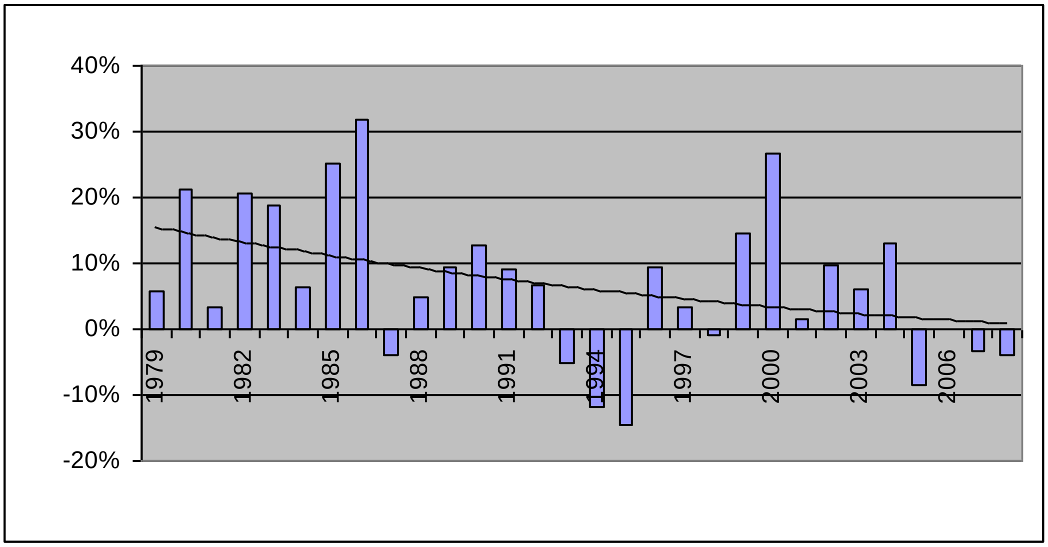
Source: The Central Bank of The Bahamas (Quarterly) from 2006-2010 and CTO Statistic Reports (various issues).

As is shown in Figure 20, tourist arrivals are declining in recent years. Table 6 presents values of this variable since 2006.

On the contrary, cruise passengers arrivals are growing from 1981 and even in recent years. This is positive in generating increasing revenues. In 2009, 71% of total arrivals were cruise passengers. In the same year, it increased by almost 400 thousands over the previous year, reaching to 3.26 million passengers, thus indicating an important recovery, although this figure could not reach the record cruise arrivals of the series, in 2004 (3.36 million). Nevertheless, average annual growth rates of cruises arrivals have a clear trend to decline, as it is shown in Figure 20.

New Providence is the most important island in The Bahamas, with Nassau, the capital of the country being the main centre of tourism, commerce and communications. Its architecture mixes well-preserved colonial premises jointly with modern and functional buildings. Green-blue beaches are located in the same city and the rest of New Providence Island, including the bridge linked tourism zone of Paradise Island. Main tourist niches in the island are sun, sand and sea products, golf, culture, nautical sports, dive and gastronomy. More than 60% of tourism infrastructure is located in about a half meter over sea level.

Figure 20: Annual growth rates of cruise passenger arrivals (%)

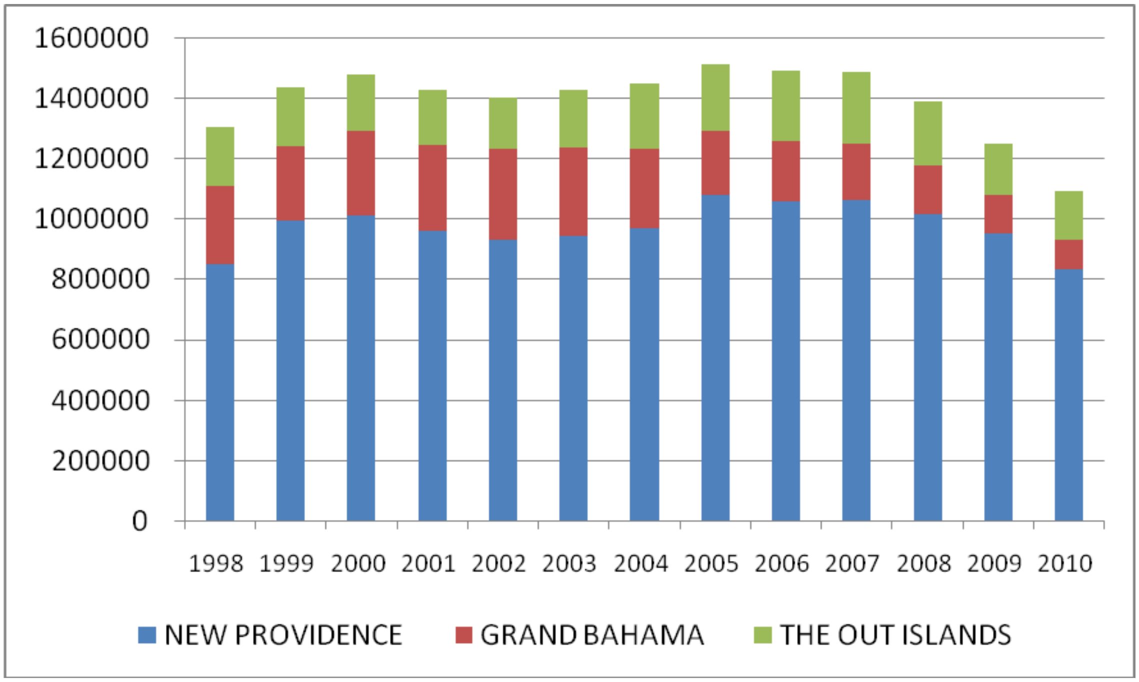


Source: Elaborated from The Central Bank of The Bahamas (Quarterly) from 2003-2011 and CTO Statistics Reports

Located at 115 kilometres off Florida and less than 3 hours from New York, Grand Bahama Island is the second most popular tourist destination in the Bahamas. The main city Freeport is an industrial and tourist developed place (hotels, casino, scuba diving facilities and other sea sports). Almost 65,000 sea yacht and boat visitors (mainly stopovers) shored in the marinas of this island. Also the Lucayan National Park is located in Grand Bahama. The park has an important underwater cave system. Similar to New Providence, Grand Bahama's tourism infrastructure is located less than 1 meter above sea level. The other islands are grouped in The Out Islands also called The Family Islands. One of them is Abaco which is the third most populous island in The Bahamas and its tourism development presents an unstable pace in arrivals, both stopovers and cruise or sea landed passengers. Marinas, boats for hire to practice life on-board, sea sports and amazing coral reefs surrounding an important group of cays are the main assets.

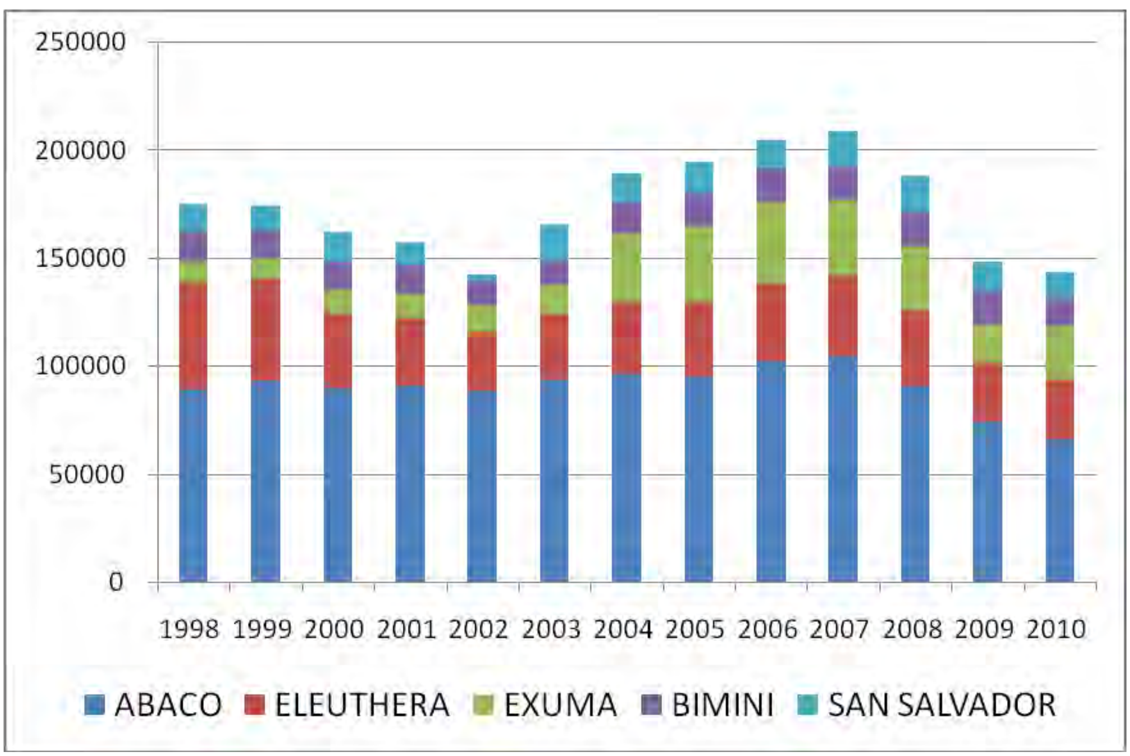
Figure 21 shows that New Providence is the main tourist destination for air arrivals; even though they are fluctuating over the last 12 years with a clear diminishing trend. Considering The Outer Islands, Abaco receives around 50 % of air arrivals among the main tourist islands of the group (figure 22).

Figure 21: Foreign air arrivals to The Bahamas by first port of entry.



Source: Ministry of Aviation and Tourism 2011 (Report of Air, Sea Landed and Cruise Arrivals 1998 – 2010)

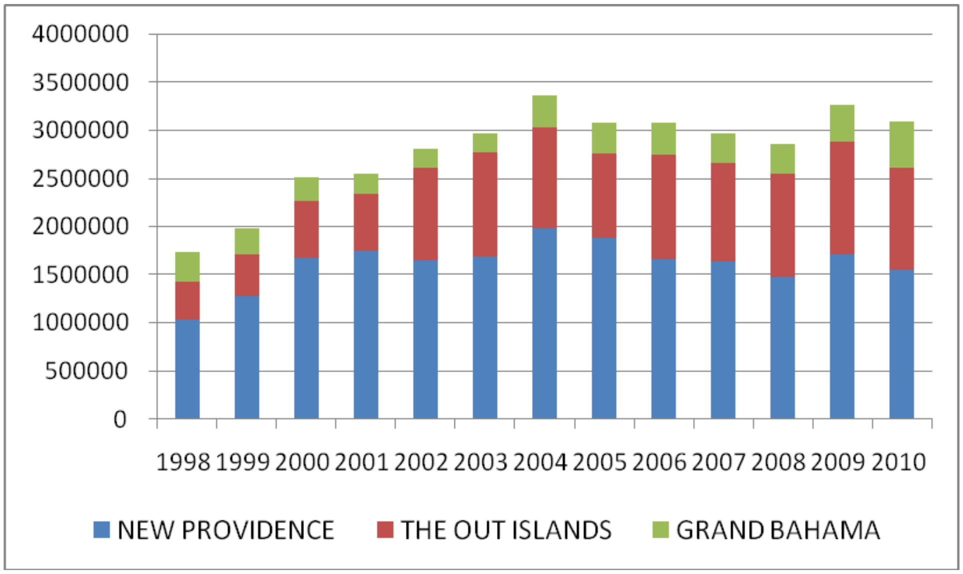
Figure 22: Foreign air arrivals to selected islands from The Out Islands, by first port of entry



Source: Ministry of Aviation and Tourism 2011 (Report of Air, Sea Landed and Cruise Arrivals 1998 – 2010)

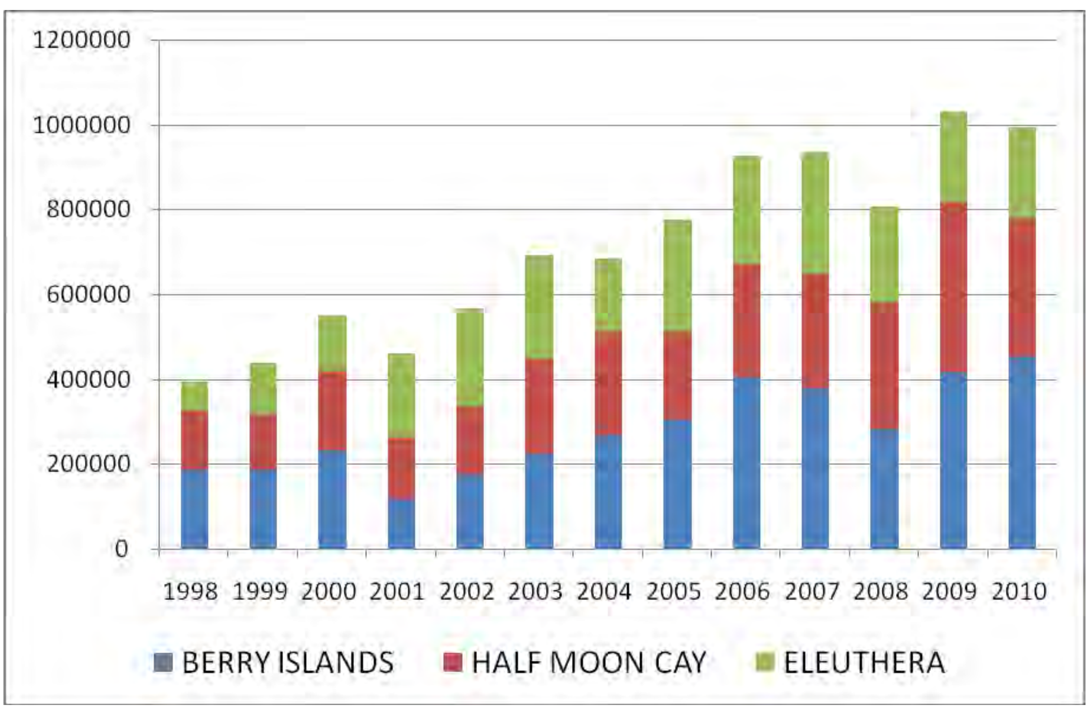
Regarding cruise arrivals, again New Providence is the most important destination for cruises in the country. Nevertheless, The Out Islands occupy second place. Inside this group, Berry Islands, Half Moon Cay and Eleuthera are important cruise destinations (with around 200 thousands cruise arrivals a year). (see figures 23 and 24)

Figure 23: Foreign cruise arrivals to The Bahamas by first port of entry



Source: Ministry of Aviation and Tourism 2011 (Report of Air, Sea Landed and Cruise Arrivals 1998 – 2010)

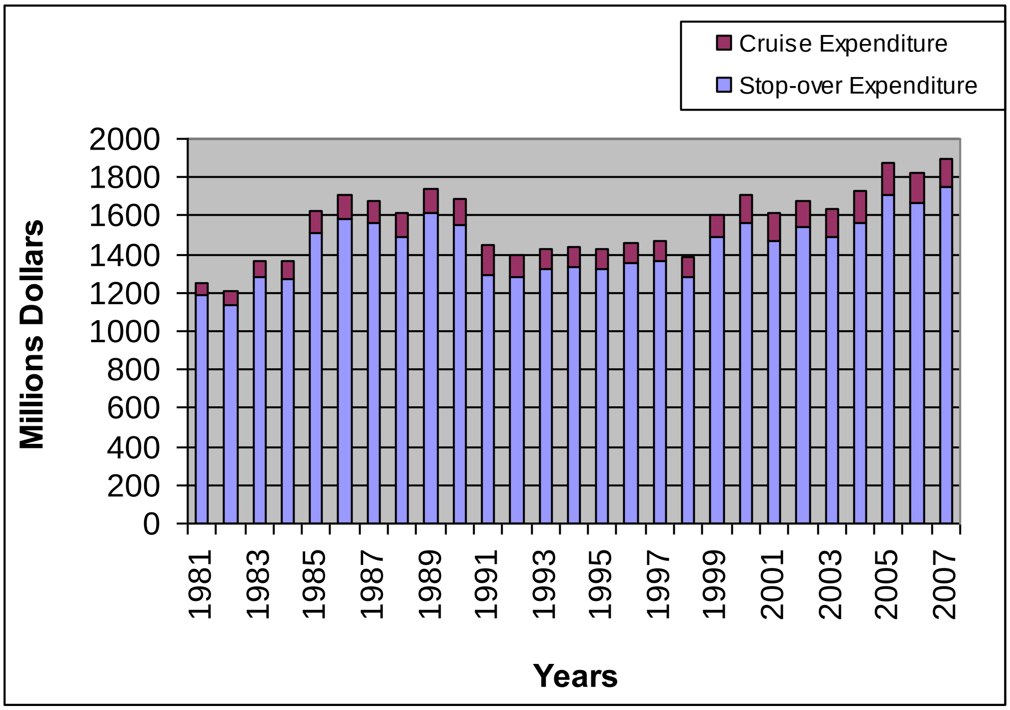
Figure 24: Foreign cruise arrivals to selected islands from The Out Islands, by first port of entry



Source: Ministry of Aviation and Tourism 2011 (Report of Air, Sea Landed and Cruise Arrivals 1998 – 2010)

Perhaps it is expedient to state that no account of specific shares for the above mentioned niches on the expenditure side exists, shortening the scope for later analysis. Visitor expenditure is steadily growing in the considered period (1981-2009) with the exception of the last two years, but they have an unbalanced share, with differences regarding types of arrivals (Figure 25). This means that even as cruise arrivals are more than visitor's arrivals and even passengers of cruise ships are growing, revenues from this niche have fewer shares in total revenues. It is a known fact in tourism sector all over the Caribbean cruises bring some money but on a small scale compared with stopover arrivals.

Figure 25: Cruise and Stopover Expenditures



Source: Elaborated from The Central Bank of The Bahamas (Quarterly) from 2003-2010 and CTO Statistics Reports

The main outbound market to The Bahamas is the United States of America. Its share in total stopover arrivals has evolved in an unstable way, but increasing annually (table 7).

Table 7: Share of US resident in total stopovers in The Bahamas 1993 – 2009 (%)

Year	Visitor Arrivals (millions)	Share
2005	930.0	58%
2006	1,538.0	96%
2007	1,263.7	83%
2008	1,176.7	80%
2009	1,068.5	81%

Source: 1992-2000: U.S. Department of Commerce, ITA, Office of Travel and Tourism Industries, December 2004; 2001-2006 USDC- ITA-OTTI; 2007-2008: CTO Latest Statistics 2008-2010

Even if visitor expenditure is growing as a rule, in summary, The Bahamas is facing similar problems as other Caribbean countries regarding the abatement of its rate of stopover arrivals (mainly by air), as it is showed in Table 8.

Table 8: Annual Growth Rate of Arrivals 1998 – 2010

	Arrivals by First port of entry		
	Air	Sea landed	Cruises
NEW PROVIDENCE	-0,1%	1.6%	3.5%
GRAND BAHAMA	-7.8%	5.2%	4.0%
THE OUT ISLANDS	-0.2%	2.4%	8.6%

Source: Elaborated from dataset of Ministry of Aviation and Tourism.

At least, four reasons determine this:

a) The exhausted model of massive tourism, motivating the development of new products in some islands (Cruises in Castaway Cay, Abaco or in Princess Cay, Eleuthera)
b) The Bahamas is an expensive destination (in concordance to the cost of life in the United States of America, its main outbound market) and the near past reflects the impact of the international economic crisis also diminishing the arrivals.
c) The tourist product transformation (more cruise passengers, huge luxury resorts, isolated real estate developments) that needs more time to penetrate the market.
d) The country needs more diversification of source markets.

D. MODELLING CLIMATE CHANGE

In this paper the Tourism Climate Index (TCI) is used as the main climate variable for modeling. This index includes climate variables such as a maximum and mean temperature, precipitation, sunshine hours, relative humidity and wind speed. As it is presented in Appendix I, the TCI is calculated with historical values (1981 – 2009 period) and it was used for projections using the dataset from PRECIS RCM (INSMET – CUBA), in Latitude 25º N and Longitude and 77,5º W, at a point near Nassau, but on the sea surface. It was the closest point to Nassau (in Latitude: 25° 03' N and Longitude: 77° 28' W) with available forecasted data, because the grid is 25km wide (figure 26). This represents a problem for TCI forecasting because of the differences in, e.g. sea surface and land surface temperature.

Historical data were obtained courtesy the Department of Meteorology of The Bahamas and it was taken at Nassau International Airport.

Figure 26: Grid point used

PRECIS RCM brings a complete dataset of climate variables on SRES A2 and B2 scenarios.

E. Variables of Tourism Demand and Supply

IPCC (2007) stated two important issues associated with assessment of economic impacts of climate change, i.e. regional and local impacts are heterogeneous and with non linear relationships and increasing over time, particularly in this century. These two aspects dictate the use of scenarios instead of accurate forecasts. Nevertheless, within the scenarios it is necessary to do forecasts of variables and to calculate some ranges to observe the likely behaviour of these variables, even considering the uncertainty for complexity of relationships and the long term considered in climate change studies.

There is a plethora of literature that demonstrates that a unique methodology do not exists to get appropriate results. On the other hand, it is necessary to identify the real transmission channels between dependent variables and the explanatory variable. In the case of climate change and tourism, there is not yet an agreed methodology to express the non-linear interactions between these variables.
Also the scenarios, the model to be used and the characteristics of these complex processes create the necessity to collect a dataset that must be consistent with the rest of the features mentioned.
There are a lot of research outcomes in the literature about the best methods to employ in forecasting tourism demand (Arche, 1976; Crouch, 1992; Enders, 2004; Frechtling, 2001; Green, 2003; Lim, 1997; Lim and McAleer, 2001a; Makridakis and others, 1998; Sinclair and Stabler, 1998; Smeral and Witt, 1996; Smeral and Wuger, 2005; Song and Wit, 2000; Song and others, 2003; Witt and Witt 1992; Song and Li 2008, Simpson 2008).

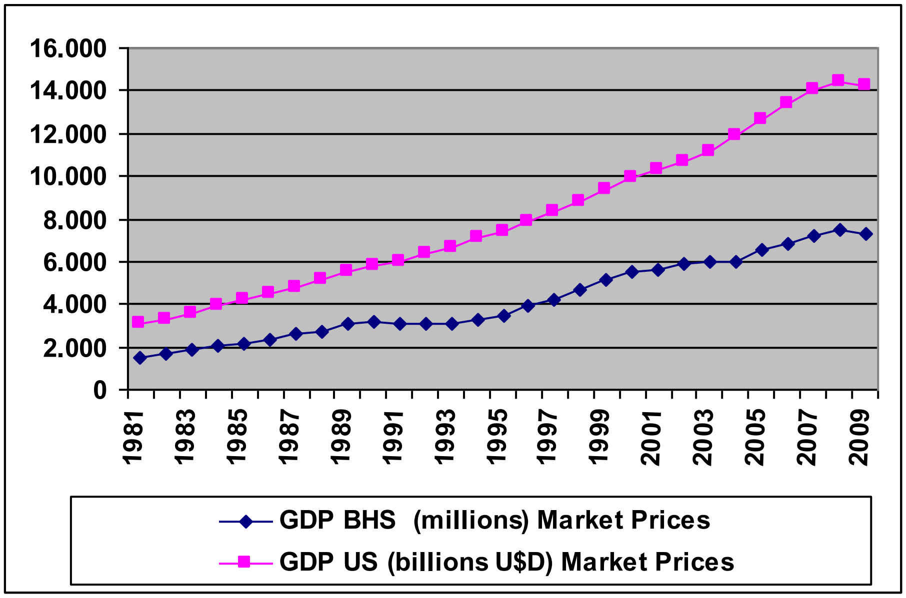
It is recognized that tourist demand has two main variable expressions, namely, visitor arrivals (tourists, cruise passengers and sea landed travellers) and visitor expenditure. The first one is commonly used for marketing purposes and the second one for economic purposes. So, in this paper visitor expenditure will be used as dependent variable.

From the demand side, in addition to climate variables, two explanatory variables will be used: Visitor Arrivals (adding Tourist Arrivals to Cruise Passenger Arrivals) and one of the main driven forces in tourist mainstream: transportation costs. Arrivals are denoted as visitors, who are divided into stopover visitors (the proper tourists, following UNWTO) and cruise passengers (excursionists in UNWTO sense). These data are raw units of thousands. This variable was considered an important causal feature for tourism expenditure. Tourists arrive in The Bahamas using mainly air transport. Only around 3% of visitors are sea landed travelers. Parts of them are stopovers (using accommodation) and the rest use their own boats and yachts as lodging. Then, air fares are directly connected with tourist arrivals, as an explanatory variable. The main component of the cost of an air ticket is the air fuel price (around 28-35%). Similarly occurs with cruise passengers, but in this case, the variable used is diesel oil prices, as a proxy for the cost of a wide range of combustible used by vessels. In both cases, the dataset was obtained from United States of America sources. As it was mentioned above, Americans are traditionally the main outbound market for The Bahamas.

Historical data for arrivals were obtained from Quarterly Statistical Digest of the Central Bank of The Bahamas and reports of Ministry of Aviation and Tourism. Visitor expenditure is the dependent variable used to assess the economic impact of climate change on the tourism sector. It is also taken from the Quarterly, up to the last year available (2009). Data are divided into stopover expenditures, cruise passengers expenditure and day visitors' expenditure, the latter being visitors who do not fall into the first two categories, but are also considered in generation of tourism expenditure. Data are presented at a rebased format, following year 2008 prices for The Bahamas.

Other economic explanatory variables will be included in visitor expenditures calculations. US Gross Domestic Product (GDP) was included considering two reasons: first, the United States of America economy has strong links with the Bahamian economy; second, it is known that the main origin markets are cities in the United States of America. Also, because most of the Caribbean's import-export business is with the United States and the majority of Caribbean tourists are U.S. citizens i.e., they earn their income to travel from this economy. The influence the U.S. economy has on the islands economy is significant. When the of the economy of the United States of America is in recession, the Bahamas' economy is also in recession, as it could be seen Figure 27.

Figure 27: Compared Gross Domestic Product (GDP) in USA and The Bahamas

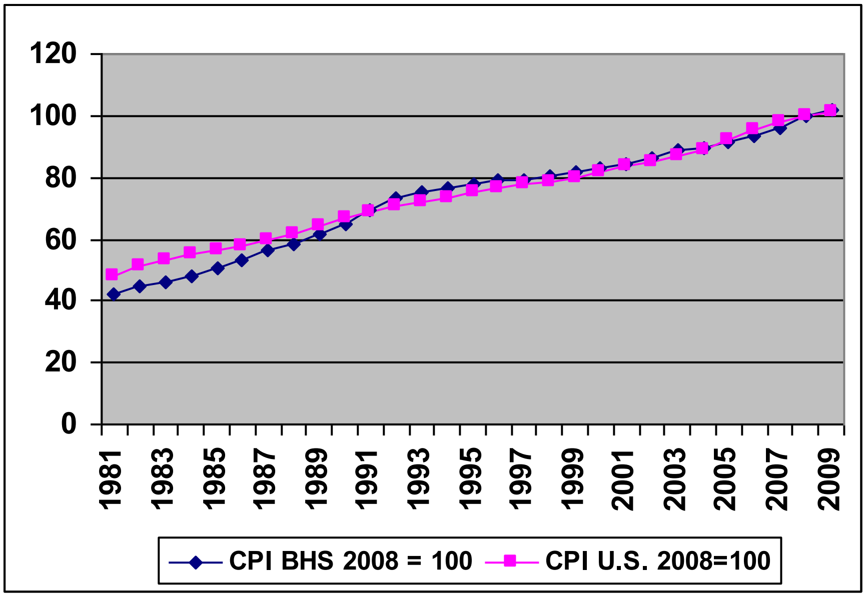


Source: US Department of Commerce, Bureau of Economic Analysis (www.bea.gov), ECLAC (2008b) and The Central Bank of The Bahamas Statistical Quarterly Digests (2003-2010)

GDP forecast has a high degree of uncertainty. The recent financial and economic world crises demonstrate the difficulty in projecting GDP. Also, long term projections have another high level of uncertainty. But the main issue is to catch an approach to present to policymakers and consider both sensitivity analysis and performance indices as ranges for covering futures possibilities in order to prepare actions that avoid hazards.

Price variables are commonly used in tourist demand forecasts. The use of Consumer Price Indices (CPI) of US and The Bahamas are determined by the fact that prices are known as explanatory variables of any kind of demand. Another issue is the proper use of CPI for long term projections. Given that the Caribbean economy is so closely linked to the performance of the U.S. economy, the U.S. dollar is also widely accepted in the region. A few of the islands even have their own currencies fixed to the United States of America dollar at a constant exchange rate. For example, one Bahamian dollar equals one U.S. dollar. Therefore, the interactions between the economy of the United States of America and the Bahamas' economy could be expressed in Consumer Price Indices too, as shown in Figure 28.

Figure 28: Consumer Price Index (CPI) in Bahamas and US

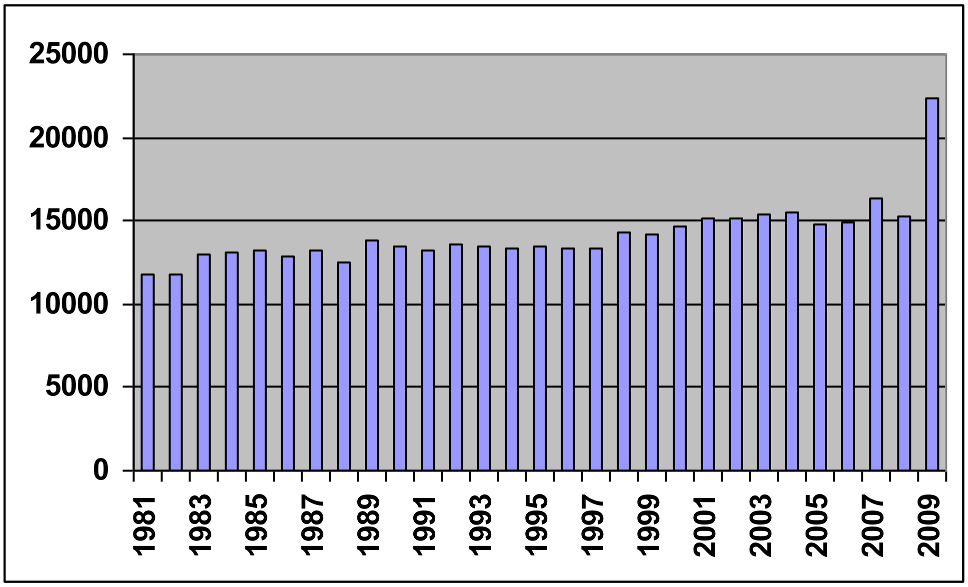


Source: US Department of Commerce, Bureau of Economic Analysis (www.bea.gov), ECLAC (2008b) and The Central Bank of The Bahamas Statistical Quarterly Digests (2003-2010)

GDP and CPI for The Bahamas are taken from the Quarterly, while CPI and GDP for the U.S. is taken from U.S. Department of Commerce Bureau of Economic Analysis. To keep pace with expenditure, all these series are rebased to 2008 prices. Price indices of the main source market and destination are taken as other main causal variables of tourism expenditure, while GDP of main market functions are taken as a proxy of purchasing power.

The introduction of the new United Kingdom Air Passenger Duty regarding climate change issues is a reality. The United States of America and Canada are not considering, at the moment, the enforcement of levies, but European countries may increase duties or Emissions Trade Systems (ETS) next year. As it was stated by Simpson (2008), "if climate policy as currently envisaged by the EU is implemented, prices for air travel would increase fairly substantially by 2012 (US\$42.2 per tonne (t) of carbon dioxide (CO_2) emitted) to reach a price level of US\$72.3 per t of CO_2 by 2020. This would translate into an estimated decline in demand by 0.6% to 1.8% in the year 2012 relative to overall holiday costs". This would be an important problem for Bahamian tourism in the near future, notwithstanding the relatively short distances between Bahamian destinations and main source markets. From the supply side, the variable lodging capacity (LC) is introduced into the mode (figure 29). It is the main variable in reference to the supply of tourist services.

Figure 29: Lodging Capacity 1981 – 2009 (Rooms)

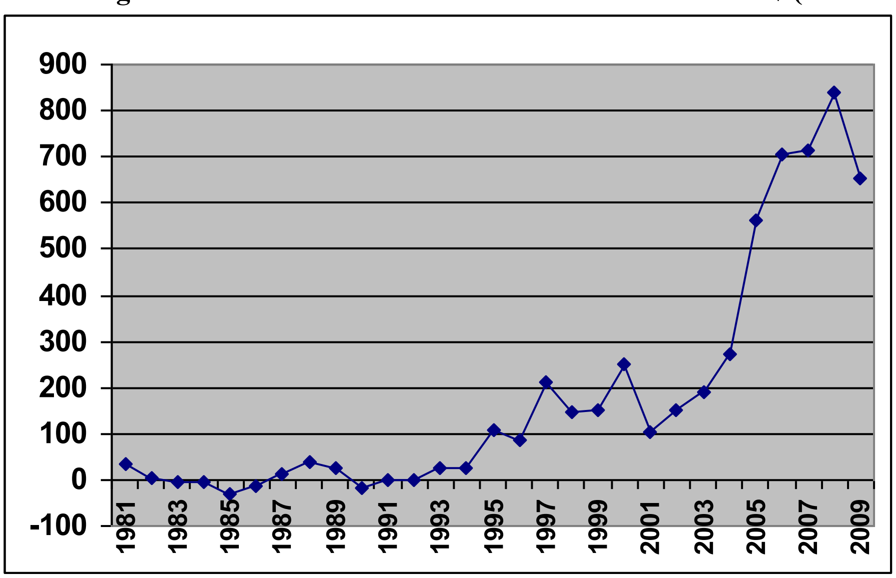


Source: Ministry of Aviation and Tourism (www.tourismtoday.com)

Lodging capacity was around fifteen thousand rooms for more than 10 years, until the year 2009 when it increased notably because of the economic recovery and policies of increased stopover arrivals. The measure of this variable is the number of rooms in accommodation entities. For The Bahamas, data were obtained from the Research Department of the Ministry of Tourism, through their official website: www.tourismtoday.com.

Also, total foreign net direct investment (FDI) is used to introduce the development approach. Data for FDI is taken from ECLAC special paper "Foreign Direct Investment in Latin America" and the statistical website of the International Monetary Fund (IMF). This was taken as a proxy for capital investments in tourism, since specific data were not available (figure 30).

Figure 30: Foreign Direct Investments in The Bahamas - millions US$ (market prices)



Source: www.imfstatistics.org

Also investment ventures (majority from US) on the islands decline and also the number of visitors from the States reduces, which in turn affects tourism, the star industry of the sub region.

.Choosing a model

Qualitative methods, usually based on experience and expertise of individuals, have been in use for quite some time now, the Delphi being one of the most commonly used. Quantitative methods can be generally divided in three major areas, which differ in the mathematical and statistical nature of the approach taken: time series, econometric (causal) and artificial intelligence methods. As the ones here employed are all quantitative, a closer look on these will be taken. The time series category deals with methods which consider the variable itself (whether tourism arrivals, average expenditure or else) in its historical development only. Relying on the chronological behavior of the variable, these methods establish the main components of time series (i.e. trend, cycle and seasonality) and then forecast the future values of the variable on a definite time frame. Examples of these methods are naive, exponential smoothing and the ARIMA (autoregressive integrated moving average) family.

The econometric category comprises the most used methods in economic variables forecasting, namely those that establish causality between variables described through unknown functions, which in this case are regularly called demand functions. Thus, an econometric model of demand (or demand model) fixes a variable describing the demand such as visitor expenditure as a function of a number of other variables that have a direct causal relation to the first one. The former is called dependent, the latter are called explanatory and the mathematical expression of the function, which is generally unknown, is approximated through specific methods. Examples of these methods range from simple regression to the statistically sophisticated Time Varying Parameters (TVP), Computable General Equilibrium (CGE) and panel data models, among others. (Kulendran and Witt, 2001, 2003; Turner and others, 1997; Turner and Wit,t 2001)

The last category is populated by the comparatively more recent approaches generally classified as Artificial Intelligence (AI). These methods, based on results that mathematically model processes in natural and human development, have been increasingly used in demand forecasting as it will be shown, with significant outcomes in comparison with the methods described above. Among these methods fuzzy logic, artificial neural networks (ANN), genetic algorithms (GA) and combinations of them, are some of the most widely employed.

In this paper, tourism demand forecasting for the Bahamas in the long range that comprises the forty years between 2011 and 2050 is attempted. Four types of demand forecast scenarios with methods belonging to two of the categories, econometrics and AI, are employed: regression in a business as usual (BAU) scenario, and regression taking into consideration SRES A2 and B2. In terms of the functional form of the demand models, there appears to be an almost universal agreement that the multiplicative (log-linear) functional form is superior to the additive (linear) form (Johnson and Ashworth 1990; Crouch 1994). The multiplicative model often fits the demand data better and conveniently provides constant demand elasticities (Morley, 1991). Such demand elasticity is then used to formulate policies and examine how consumers respond to changes in demand variables. However, a study by Qiu and Zhang (1995) found that the estimation of functional forms (log-linear and linear forms) could show variation from country to country; suggesting that the linear form can also be useful with particular types of data.

Taking into consideration the different methods and techniques found in the literature, and due to its features, it was decided to employ an Artificial Neural Networks approach. Recently, the use of artificial neural networks (ANNs) instead of multiple regression analysis has gained popularity in different fields (Gorr, 1994). A number of studies have also used ANNs in the area of tourism and hospitality with respect to market segmentation (Mazanec, 1992, Bigné and others, 2008, Delgado and

Fernández, 2010, Delgado and Abreu, 2010), destination choice behavior modeling (Jeng and Fesenmaier, 1994), product positioning (Mazanec, 1995) and visitor behaviour (Pattie and Snyder, 1996).

Then, the demand functions used are represented by the formulae:
TA_t (Tourist arrivals) = f ($AirCost_t$, TCI_t) and, subsequently for cruise arrivals
CA_t (cruise arrivals) = f ($Dieselprices_t$, TCI_t)
VA_t (visitor arrivals) = $TA_t + CA_t$
Then, visitor arrivals include the climate component and one of the main influence factors: cost of transportation. Of course, for the BAU projections, only fuel prices were considered as explanatory variables, not including TCI, since BAU is a "climateless" scenario.

The demand model of visitor expenditure (VE) (dependent variable) was constructed as a function of the following (taken as explanatory) variables: total number of visitors arrivals (VA), Consumer Price Index (CPI) of Bahamas, CPI of United States, GDP of U.S., Foreign Direct Investment (FDI), lodging capacity of Bahamas (LC)
Thus, the different models can be written as follows:
BAU: VE-BAU = f (VA projected, CPIBhs, CPIUS, GDPUS, LC, FDI)
A2: VE-A2 = f (VA-A2, CPIBhs, CPIUS, GDPUS, LC, FDI)
B2: VE-B2 = f (VA-B2, CPIBhs, CPIUS, GDPUS, LC)
Data for the variables selected with the models was analyzed in search for outliers and other error generating causes.

Summary of scenarios for modelling

Business as usual (BAU) scenario is the baseline calculated only for comparisons interest. It is forecasted using non-linear time series of its explanatory variables from an historical dataset of 28 years. It is important to note that the BAU scenario will never exist because GHG emissions continue and increase in a larger proportion than ever before.
On the other hand, SRES A2 and B2 were used to reflect the impact of climate change on dependent variables (Visitor arrivals and Visitor Expenditure). Climate data for these scenarios helped to build the corresponding TCIs, which in turn were used as explanatory variables to forecast arrivals.

Finally, a number of different ANN methods were employed to find the best fitting and subsequent forecast. Generalized Regression, Radial Basis Functions and Multilayer perceptrons were the most widely used. Their performance, error measures and other statistics are found in Appendix III.

IV. DISCUSSION OF MODELING RESULTS

A. VISITOR ARRIVALS

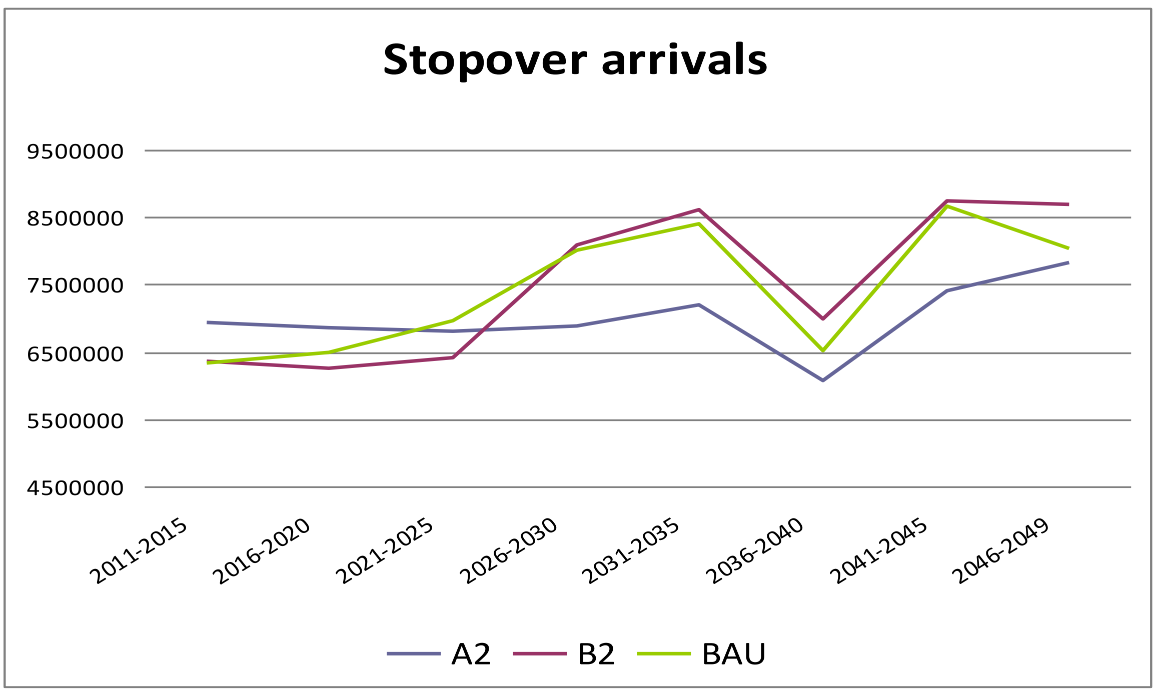
Results from models are presented in this section. Numbers of arrivals are estimated to be larger in the SRES B2 scenario, with nearly 60 million stopover arrivals to The Bahamas in this projection, representing an excess of 5 million of potential passengers in comparison with the SRES A2, which is estimated to account for 56 million passengers in the time frame considered (table 9 and figure 31).

Table 9: Stopover arrivals in A2, B2 and BAU Scenarios (Passengers).

Scenario	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
A2	6925400	6854965	6797449	6877260	7186008	6081297	7410969	7830153
B2	6347527	6255425	6415670	8086169	8604408	6981452	8748053	8677620
BAU	6322057	6479122	6950599	8008258	8390993	6525712	8664734	8044891

Source: Author's compilation

Figure 31: Estimated number of stopovers per scenario 2010-2050.



Source: Author's compilation

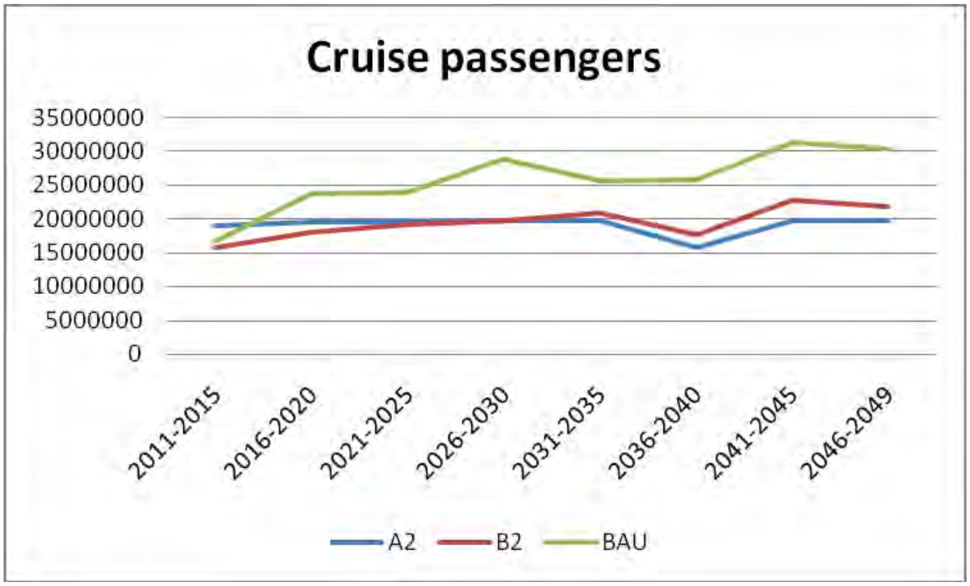
Cruise arrivals are expected to behave in the same way, this time with a slightly higher than the BAU scenario, with 35 and 32% more passengers than A2 and B2 SRES, respectively. This is consistent with the idea that in a Business as Usual scenario, the structure of arrivals must reflect the historical behavior, in which growing numbers of cruise passengers and steady (or decreasing) numbers of stopovers is the common trend (table 10 and figure 32).

Table 10: Cruise passengers in A2, B2 and BAU Scenarios

Scenario	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
A2	18949239	19510840	19592514	19643970	19633109	15757613	19690648	19632586
B2	15729452	18071922	19232638	19847258	20857936	17714754	22865068	21944488
BAU	16759475	23825051	23969645	28919753	25614308	25947238	31347005	30451673

Source: Author's compilation

Figure 32: Estimated number of cruise passengers per scenario, 2010-2050

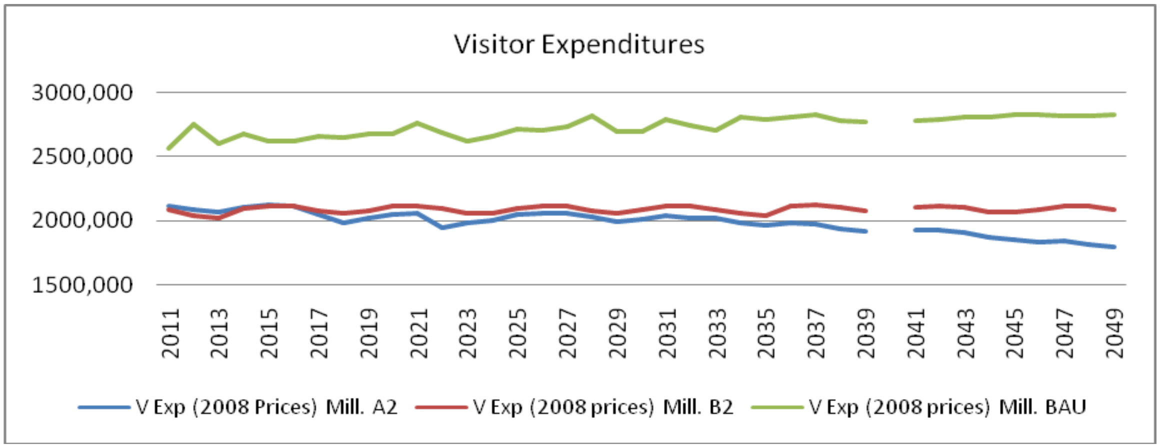


Source: Author's compilation

B. EXPENDITURE: NOMINAL AND DISCOUNTED.

On the other hand, expenditure are estimated to be larger in the comparative BAU scenario, in which nearly U.S. $ 100 000 million are expected to accumulate by the end of the period. SRES B2 and A2 have more discrete figures, well under the 100 000 million United States of America dollars level, although in comparison, the B2 scenario will have better results, with expenditure every decade over the 20,000 figure (table 11 and figure 33). SRES A2 shows signs of a declining trend, with expenditure expected to be cumulative below 20,000 million in the final decade.

Figure 33: Estimated number of expenditure per scenario 2010-2050



Source: Author's compilation

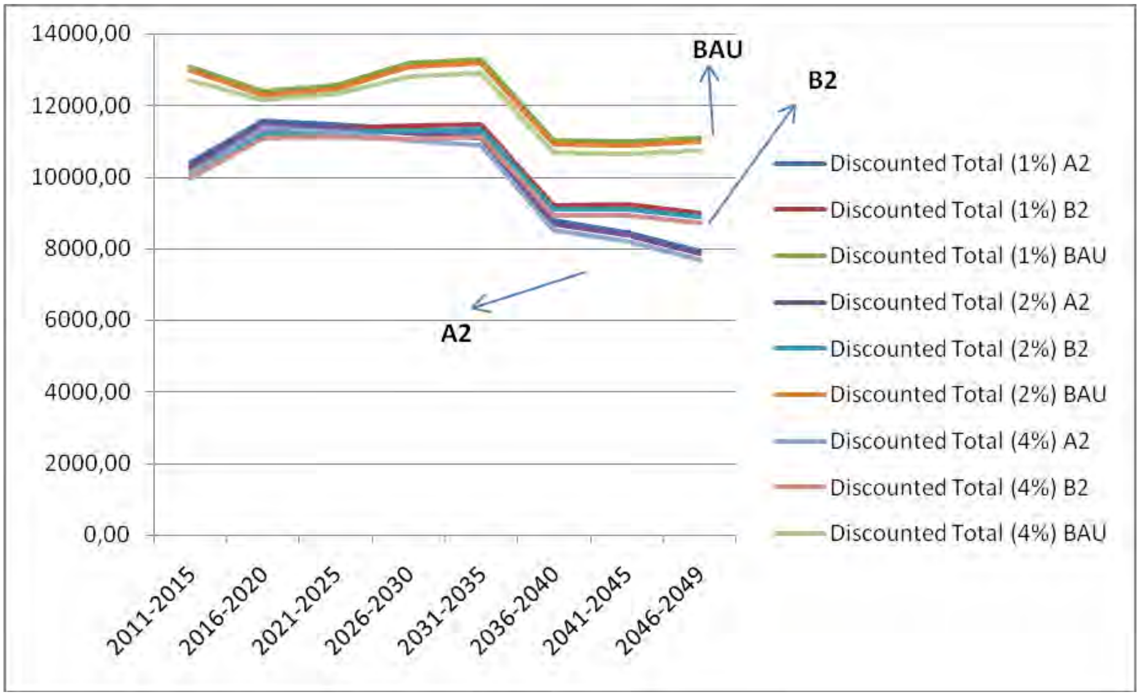
Table 11: Visitors' expenditure in BAU, B2 and A2 Scenario (Millions)

		2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
T Exp (2008 Prices) Mill.	A2	10499,15	12679,18	11604,38	11465,01	11308,17	8862,18	8540,36	8008,05
	B2	10351,11	12342,59	11453,21	11521,51	11564,38	9289,81	9315,72	9090,20
	BAU	13215,21	12216,06	12695,13	13312,92	13433,21	11119,67	11099,21	11203,43

Source: Author's compilation

The pattern described in the nominal expenditure estimates is reproduced when discounted estimates are analyzed. Effectively, the BAU scenario sums the best results, followed by SRES B2 and A2 scenarios in that order, although differences between figures are shortened in comparison with nominal expenditure, as expected (table 12 and figure 34).

Figure 34: Discounted number of expenditure per scenario 2010-2050



Source: Author's compilation

Table 12: Discounted expenditure in BAU, B2 and A2 Scenario (Millions). Rates of 1%, 2% and 4% are employed.

Concept	Scenario	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
Discounted Total (1%)	A2	10394,16	11579,34	11488,33	11350,36	11195,09	8773,55	8454,96	7927,97
	B2	10247,60	11311,41	11338,68	11406,29	11448,73	9196,91	9222,57	8999,30
	BAU	13083,06	12391,86	12568,18	13179,79	13298,88	11008,47	10988,22	11091,40
Discounted Total (2%)	A2	10289,17	11463,55	11373,45	11235,71	11082,00	8684,93	8369,56	7847,89
	B2	10144,09	11198,29	11225,30	11291,08	11333,09	9104,01	9129,41	8908,40
	BAU	12950,91	12267,94	12442,49	13046,66	13164,55	10897,27	10877,23	10979,36
Discounted Total (4%)	A2	10079,19	11348,91	11259,71	11006,41	10855,84	8507,69	8198,75	7687,73
	B2	9937,07	11086,31	11113,04	11060,65	11101,80	8918,22	8943,09	8726,60
	BAU	12686,61	12145,26	12318,07	12780,40	12895,89	10674,88	10655,24	10755,29

Source: Author's compilation

C. SCENARIO ON EXTREME EVENTS

The main tourism attraction losses linked with climate change were exposed above, namely the sea level rise, occurrence of extreme events like hurricanes and ocean acidification. Following Williams and Sheets (2001), the capital and Nassau area in New Providence Island along with nearby Paradise Island (in fact, a circle of a 75 miles radius centered at Nassau coordinates), are expected to experience 22.2 hurricanes in this century, of which around 9 should be major hurricanes, that is, category 3 or above in Saffir-Simpson scale. On the assumption that hurricane probabilities are equally distributed all around the century, it is possible that some 11 hurricanes, of which 5 could be reported as major would affect Nassau and the surroundings before 2051. This set the stage for a cost scenario, which has the same probability as any other possible (logical) combination.

A hurricane-class tropical cyclone hit the area once in a 5-year period, starting at 2011. Tropical cyclones affecting The Bahamas had a near exact cycle of three years from 1981-2009. With the global consensus about a lower or similar frequency of tropical cyclones for this century, this is plausible. Hurricane intensity cycles in alternate occurrence of a 4-5 category hurricane with a category 1 hurricane.

Growing intensity of hurricanes, related to very good conditions in the low level atmosphere and both below and above, is commonly accepted throughout the literature as powerful probability for this century. This "rate" is also sustained by the common opinion of local experts in The Bahamas[5].
Upon these assumptions, table 13 which incorporates data from the scenario is constructed. Hurricanes appear as mentioned, once in every 5-years period, starting in 2011. Per hurricane/year, the following data are resumed: category (H. Category), which is the Saffir-Simpson scale category for the hurricane; cumulative sea level rise (Cum. SLR) which is the accumulated sea level rise for that year; maximum sustained winds (Max. Sust. Winds), which is the speed measured in meters per second (m/s) of maximum 1 minute sustained winds of the storm and storm surge plus SLR, which is the storm tide height above sea level plus the sea level rise projected for that period.

Table 13: Hurricanes and SLR: Combined destruction power scenario. Percentages

Year	H. Category	Cum. SLR (cm)	Max. Sust. Winds (m/s)	Storm Surge + SLR (m)
2011-2015	4	0.13239261	59-58	3.9-5.6
2015-2020	1	0.179177819	33-42	1.1-1.9
2021-2025	5	0.228125312	>69	>5.6
2026-2030	1	0.27815683	33-42	1.3-1.9
2031-2035	4	0.33239261	59-58	3.9-5.6
2036-2040	1	0,37946183	33-42	1.3-2.0
2041-2045	5	0.430342209	>69	>5.6
2046-2050	1	0.451273636	33-42	1.4-2.1

Source: Elaborated following SLR projected data, Moore and others (2010) and scenario conditions.

According to Moore and others (2010) the following are estimates of potential damages derived from hurricane impact (see table 14):

[5] This was one of the agreements of the author´s meeting with the National Climate Change Committee (NCCC) of The Bahamas.

Table 14: Hurricane potential damage by category.

Saffir/Simpson (SS) scale	*Maximum Sustained Wind Speed (m/s)*	*Storm Surge(m)*	*Potential Infrastructural Damage*
Category 1	33-42	1.0-1.7	No major damage to buildings (5%)
Category 2	43-49	1.8-2.6	Moderate damage to buildings (10%)
Category 3	50-58	2.7-3.8	Extensive damage to buildings (35%)
Category 4	59-58	3.9-5.6	Extreme damage (50%)
Category 5	>69	>5.6	Catastrophic damage (75%)

Source: Moore and others, 2010.

On the other hand, Simpson and others (2009) estimated the damage from a rise in sea level in a range from 1 to 6 meters in The Bahamas (Table 10, Chapter 3). From those estimates, and considering flooding from storm surge (plus the sea level at the time) delivering the same damage as those projected by Simpson and his colleagues for sea level rise (at same sea height) table 15 is built.

Table 15: Scenario percentage damage.

Period	Hurricane Category	Potential damages	Structures potential damages	Adjustment
2011-2015	4	50%	MTR(35%), Airports (81%), Roads (30%)	40%
2015-2020	1	5%	MTR(10%), Airports (19%), Roads (4%)	10%
2021-2025	5	75%	MTR(50%), Airports (91%), Roads (43%)	50%
2026-2030	1	5%	MTR(13%), Airports (22%), Roads (5%)	10%
2031-2035	4	50%	MTR(35%), Airports (81%), Roads (30%)	40%
2036-2040	1	5%	MTR(13%), Airports (22%), Roads (5%)	10%
2041-2045	5	75%	MTR(50%), Airports (91%), Roads (43%)	50%
2046-2050	1	5%	MTR(13%), Airports (22%), Roads (5%)	10%

Source: Elaborated following SLR projected data, Simpson and others (2009) and scenario conditions.

The table should be read as follows: Period and Hurricane categories explain themselves. Potential damage represents a percent of any infrastructure (buildings and roads) potentially damaged as result of hurricane impact. Structures potential damages refer to Simpson and others, 2010 estimate of sea level rising damage, in this case for the sea height reached by storm surge plus SLR for the period found in Table 19. Here, as in the cited paper, MTR stands for Major Tourism Resorts (in this case 4-5 star hotels). The Adjustment column tags on the following logic: Simpson and others (2010) estimates are from uniform sea level rise, which is an event occurring in all of The Bahamas at the same time and pace. Due to the fact that we are considering local non-uniform phenomena (storm surges, although they might spread for a long range of coastline, are always local to the point the storm is at one given time) it would be unrealistic to assume a uniform distribution of damages throughout the whole country. Instead, depending on the intensity of the hurricane (and thus area affected by the hurricane) a percentage of damage coverage is adjusted, to bring more down-to-earth estimates of storm damage. As a result, for example first line of Table 21 should be read: "In the 5-year period of 2011-2015 a category 4 hurricane in Saffir-Simpson scale striking The Bahamas could potentially damage 14% (40% of 35%) of Major Tourism Resorts (rooms), 32.4% (40% of 81%) of airports facilities and 12% (40% of 30%) of roads. Each of these structures might be damaged up to a 50% of their value."

Table 16 shows the associated cost for the damage depicted above. Values for MTR rooms, airport facilities and roads kilometers are taken from Simpson and others (2010) estimates for the Caribbean. Please note that these are costs of gradual sea level rise and hurricane activity. All estimates are in 2008 US dollars.

Table 16: Combined destruction power scenarios - total damage.

Year	H. Category	MTR Damages	Airport Damages	Road Damages	Totals per period
2011-2015	4	$ 46.460.400,00	$ 242.190.000,00	$ 81.057.600,00	$ 369.708.000,00
2015-2020	1	$ 331.860,00	$ 1.420.250,00	$ 270.192,00	$ 2.022.302,00
2021-2025	5	$ 124.447.500,00	$ 510.168.750,00	$ 217.842.300,00	$ 852.458.550,00
2026-2030	1	$ 1.294.254,00	$ 1.644.500,00	$ 337.740,00	$ 3.276.494,00
2031-2035	4	$ 46.460.400,00	$ 242.190.000,00	$ 81.057.600,00	$ 369.708.000,00
2036-2040	1	$ 464.604,00	$ 1.644.500,00	$ 405.288,00	$ 2.514.392,00
2041-2045	5	$ 124.447.500,00	$ 510.168.750,00	$ 217.842.300,00	$ 852.458.550,00
2046-2050	1	$ 497.790,00	$ 1.644.500,00	$ 472.836,00	$ 2.615.126,00
Totals per type of structure		$ 344.404.308,00	$ 1.511.071.250,00	$ 599.285.856,00	$ 2.454.761.414,00

Source: Elaborated following SLR projected data, CIA (2009), Simpson and others (2009), Bahamas Guide (2010b) and scenario conditions.

It can be seen that a grand total of more than 2,400 million United States of America dollars in damage might be attributed to extreme events (namely hurricanes) activity in the area for the time considered, along with the steady rise in the sea level. As stated in the previous section, airport facilities might endure the higher costs of damage, due to their construction characteristics and proximity to the sea.

Unfortunately, the value of the economic damages representing wetlands losses and coral reefs bleaching and/or destruction, are not yet available from the specialized research. As important assets for tourism in The Bahamas, extreme events impacts (Sealey, 2003; Gardner and others, 2005) might even bring considerably more damage than projected in the constructed scenario, if these physical impacts on biodiversity (and their correspondent transferred costs for tourism) could be accounted for. A research project started in 2006, which is being conducted by the World Resources Institute to assess the economic value of coastal capital in the Caribbean, i.e. coral reef and mangrove associated ecosystems, although no results have been yet attained regarding The Bahamas (WRI, 2010).

D. SUMMARY OF ECONOMIC IMPACTS

The process of measuring economic impacts (a reduction in tourism expenditures in constant 2008 prices) and losses associated to impacts on tourism in the scenario described in last section is reflected in Table 17.

Table 17: 5-year period impacts of extreme events scenario discounted at 1%, 2% and 4%, in Millions of US$.

Concept	Scenario	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
Damages&Destruction 1%	Own	366,01	368,01	1211,95	1215,19	1581,20	1583,69	2427,62	2430,21
Damages&Destruction 2%		362,31	364,30	1199,71	1202,92	1565,23	1567,69	2403,10	2405,67
Damages&Destruction 4%		354,92	356,86	1175,22	1178,37	1533,29	1535,70	2354,06	2356,57

Source: Author's compilation

Finally, by adding discounted losses in visitor expenditures (SRES B2 and A2 compared to BAU expenditures) to damage and destruction from the extreme events scenario, an estimate is obtained of the total impact of climate change on the tourism sector in The Bahamas (see table 18).

Table 18: Total impacts of climate change in the tourism sector in The Bahamas discounted at 1%, 2% and 4%, in Millions of USD.

Concept	Scenario	2011-2020	2021-2030	YTD 2030	2031-2040	YTD 2040	2041-2049	YTD 2050
At 1%	A2	3869,43	3756,45	7625,88	4707,21	12333,09	6543,21	18876,30
	B2	4283,93	3850,17	8134,10	4030,21	12164,31	4704,27	16868,58
At 2%	A2	3830,43	3718,61	7549,04	4659,67	12208,71	6477,12	18685,82
	B2	4240,77	3811,40	8052,17	3989,50	12041,67	4656,75	16698,43
At 4%	A2	3760,63	3653,85	7414,48	4564,57	11979,05	6344,93	18323,98
	B2	4165,36	3746,28	7911,64	3908,08	11819,73	4561,72	16381,44

Source: Author's compilation

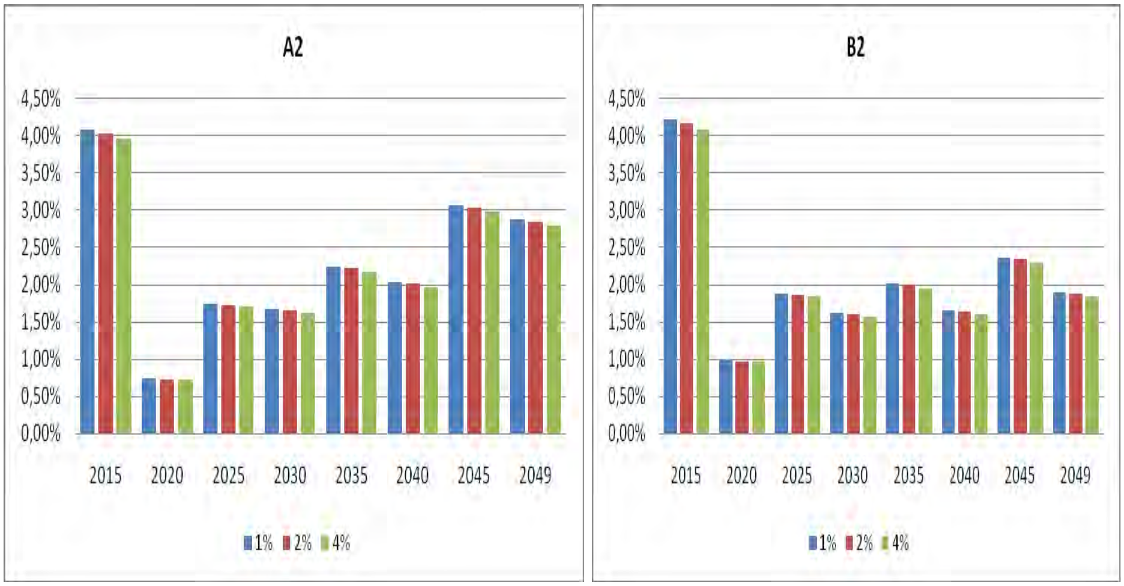
As it can be seen, between 17 000 and 19 000 millions of USD will be lost due to the impacts of climate change in the tourism sector of The Bahamas. Measuring the percentage of share of Bahamian 2008 GDP represented by these losses every 5 years (table 19 and figure 35).

Table 19: Impacts of climate change in the tourism sector discounted at 1%, 2% and 4%, in Millions of USD, represented by % share of the 2008 GDP of The Bahamas.

A2				**B2**			
Year	1%	2%	4%	Year	1%	2%	4%
2015	4.07%	4.03%	3.94%	2015	4.20%	4.16%	4.07%
2020	0.74%	0.73%	0.72%	2020	0.98%	0.97%	0.96%
2025	1.74%	1.72%	1.70%	2025	1.88%	1.86%	1.83%
2030	1.66%	1.64%	1.61%	2030	1.61%	1.59%	1.56%
2035	2.23%	2.21%	2.17%	2035	2.01%	1.99%	1.94%
2041	2.02%	2.00%	1.96%	2041	1.64%	1.62%	1.59%
2045	3.06%	3.03%	2.96%	2045	2.36%	2.34%	2.29%
2049	2.86%	2.84%	2.78%	2049	1.90%	1.88%	1.84%

Source: Author's compilation

Figure 35 a) A2 impacts b) B2 impacts (as % of 2008 GDP)



Source: Author's compilation

Moreover, if Government Total Tourism Tax Revenue is around 33% of visitors expenditures (Sacks, 2006), then losses can be measured by lost government tax revenues which are estimated as it is shown in table 20.

Table 20: Lost Government Total Tourism Tax revenue due to losses in visitor expenditures. 5-year periods. Millions of B$.

Estimated losses in Government Total Tourism Taxes, 5-years periods. Millions of BHS.									
Concept	Scenario	2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2049
At 1%	A2	886,80	267,97	356,13	603,34	693,83	737,08	835,47	1043,30
	B2	935,14	356,33	405,49	584,90	610,18	597,45	582,31	689,97
At 2%	A2	877,84	265,29	352,57	597,25	686,82	729,63	827,03	1032,76
	B2	925,69	352,77	401,43	578,99	604,02	591,42	576,43	683,00
At 4%	A2	859,93	262,64	349,05	585,06	672,81	714,74	810,15	1011,68
	B2	906,80	349,24	397,42	567,17	591,69	579,35	564,67	669,06

Source: Author's compilation

As a result, between 4.6 and 5.4 billions of Bahamian dollars will be lost to the central government in the whole period, a serious number taking into account that government tax revenues are around 1.3 billions of Bahamian dollars each year.

V. ADAPTATION AND MITIGATION OPTIONS

A. Comprehensive list of Adaptation – Mitigation measures

A list of possible actions of adaptation / mitigation to carry out in The Bahamas is prepared. The tables presented below are derived and taken from a group of papers and reports[6]. Each proposal is classified considering its use for adaptation, mitigation or both. Secondly, it includes the main stakeholders implicated in the implementation of the action. As the role of regional organizations was previously highlighted, the national stakeholders are now also highlighted. Particularly on mitigation, UNWTO (2009) listed a number of mechanisms that could be used to diminish GHG such as reducing energy use, improving energy efficiency, increasing the use of renewable energy, among others. All of these ideas are included in tables presented in Appendix IV.

B. Cost-Benefit Analysis of selected options.

A long list of measures for adaptation, mitigation or both was revisited, and five measures were selected using the following filtering criteria:

1. Mitigation actions, although of little global impact, might enhance Bahamian destinations in two different senses: Reduce dependence on fossil fuels, which are entirely imported for the country and, of no less importance, they provide most needed improvement in destination image, in connection with criteria exposed here the reasons behind stopover declines and future tourism trends.

2. Adaptation actions are needed to countermeasure possible damage and destruction derived of self-constructed scenario.

3. A whole section of strategies and measures are based on studies and organizational actions, of which no economic valuation could be attained by the authors under current conditions.

1. Pursuit of Low-carbon Tourist Economy

As mentioned above, arrivals have remained fairly increasing for most of the period but in the last three years the data showed a perceptible decline in stopover visitors to The Bahamas. Despite an increase in hotel prices, a transformation in the image of Bahamian destinations towards a low-carbon tourist economy is needed. Some actions for energy-saving in the tourism sector are developed, but they are not enough because of these vulnerabilities:

- High dependence on imported energy and increasing costs of oil and by-products.
- The need to reduce the high index of emissions per capita, to enhance the position of the country in international negotiations on climate change action funding.

A new programme needs to present not only energy-saving measures but also the use of renewable technology such as the use of wind for electricity generation. In summary, The Bahamas needs to be a lot more energy efficient to achieve the goal of being a Carbon Neutral Tourist Destination, the

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[6] Attzs (2002); CDERA (2003); BEST (2001 & 2005); NCCC/BEST (2005); UNWTO (2007); Scott & Simpson (2008); Simpson and others, (2008 a, b); CRSTDP/CTO/EC/CBIS (2008); Caribsave/CCCCC/U Oxford (2009); Caribsave (2009); CCCCC (2009); ECA (2009); LGCB/CDERA (2009); ECLAC (2009h); CAST/UNEP (2009); NRC-US (2010b); ECA/CCRIF (2010); UNWTO (2010) and Sookram (2010a / 2010b).

desirable situation for a destination image today and in the future. In a study of Crete Island, Konstantinos and others (2010) demonstrated that 87% of the respondents would prefer to stay in hotels with Renewable Energy Systems (RES) rather than staying in hotels of identical quality which do not have it and also 77% of respondents would be willing to pay fee surcharges for a hotel equipped with RES. Finally, Konstantinos expressed that "Tourists from countries with high energy awareness, prove to be more willing to choose to stay at and pay for hotels with RES". Unfortunately, by the preponderance of US on Bahamian tourism sector, and following Simpson and others (2008a) "travelers from the United States (US) would be the less likely to reduce their demand for the region although most believed this would happen eventually as awareness gradually raised in the US origin market". But even in this case, The Bahamas is promoting itself in new markets.

The action proposed focuses on implementation of a Renewable Energy System (RES) using a Hybrid system equipment of 40 light wind energy conversion system (WECS) type AOC 50 Kw each, 600 kW converter and 500 battery set, plus a 600 kW back-up diesel generator, with implementation costs of 7.9 US$ millions. It generates enough energy to power a hotel of 388 rooms.

Assumptions, following Dalton and others (2008a, 2008b) are:

- The system is supposed to have a lifetime of 20 years (2014-2034).
- Net present cost (NPC), Initial Cost (IC) and Cumulative cash flow are represented in millions of dollars at 2008 current prices and then discounted with three rates (1, 2 and 4%).
- Inflation factor was obtained from own forecast of CPI Bhs (1,0055)
- Renewable Factor (RF) refers to the percentage of the total production originated in renewable energy use by each system (0, 64).
- Saving in energy costs is the difference between cost of renewable energy and fossil energy = US 1,024 million dollars.
- The number of tons of CO_2 per year offset by RES Hybrid is 2637,4
- Carbon offsetting price = US$ 12.64 (from The Carbon Neutral Company – UK)
- Maintenance costs = US 176,0 thousand dollars

Table 21: Benefit-cost ratio and net payback time at different discount rates for a low carbon economy

Discount Rate	1%	2%	4%
Net Benefit-Net Cost Ratio	5.8	1.6	1.4
Payback Time (years)	10	10	11

Source: Data compiled by author

In all discount rates alternatives are acceptable, taking into account that investments in renewable energy are recovered in more time than fossil fuel ones (table 21).

2. Resilience on impacts of extreme events on major tourism resorts (MTR)

MTR will suffer the loss of 338 rooms in the first five years as a consequence of the passing of one category 4 hurricane (3rd year of the project) with a correspondent cost avoidance of $ 46.5 million United States of America dollars. Also, another two hurricanes (categories 1 and 5 in years 8th and 14th) will affect the country in $ 0.3 and $ 124.5 million United States of America dollars. The action consists in moving threatened and damaged hotel rooms to higher elevations (Measure 29), based on following alternatives and assumptions:

a. Rebuild or construct 338 hotel rooms with a development costs of $ 80 thousand US dollars per room (Simpson and others, 2009). Implementation costs = $ 31 US million dollars. Daily room rate as 2009 (US $200)

b. The same number of rooms but with a development costs of $ 120 US thousand dollars per room (Fish and others, 2008). Implementation costs = $ 46,6 US million dollars. Daily room rate as high hotel category (US $ 300)

Table 22: Benefit-cost ratio and net payback time at different discount rates for resilience-building at MTR

	Average Daily Rate $200 US			Average Daily Rate $300 US		
Discount Rate	1%	2%	4%	1%	2%	4%
Net Benefit-Net Cost Ratio	3.15	3.02	2.78	2.40	2.32	2.17
Payback Time (years)	3	3	3	3	3	3

Source: Author's compilation

Good ratios are obtained for this kind of businesses.

3. Resilience on impacts of extreme evernts at airports

As it is stated in the scenario, the country could suffer the loss of an airport in the first five years of the considered period, as a consequence of one category 4 hurricane (year 3rd of the project) with a correspondent cost avoidance of $ 242.2 million United States of America dollars and other cost avoidance of $ 1.4 US million dollar in year 8.

The action is to build a new airport in a safe place, using the following assumptions:

- Implement costs = $ 65 million United States of America dollars (Simpson and others, 2009)
- Gross airport income and government revenue: $5 million United States of America dollars of services (proxied by two international airports) and 10% of stopover arrivals by departure tax of $55 United States of America dollars.
- Operational and maintenance costs: 40 % of gross income (same proxy) and 1 % on implement costs as additional set-up costs.

Table 23: Benefit-cost ratio and net payback time at different discount rates for resilience-building at airports

	New Airport		
Discount Rate	1%	2%	4%
Net Benefit-Net Cost Ratio	4.61	4.89	5.27
Payback Time (years)	3	3	3

Source: Data compiled by author

It is possible to consider this action.

4. Resilience to impacts of extreme events on roads

The action focuses on road construction of 62.4 km that could be impacted by category 4 hurricane in year 3rd (cost avoidance $ 81.01 million United States of America dollars), plus another two impacts (years 9th and 15th with costs avoidance of $ 0.27 and $ 217.8 million dollars respectively).

The assumptions for this action are:

- Implement costs = US$ 54,0 millions (Simpson and others, 2009).
- Operational costs and maintanence: 5 % of initial implement costs.

Table 24: Benefit-cost ratio and net payback time at different discount rates for resilience-building of roads

	New Road		
Discount Rate	1%	2%	4%
Net Benefit-Net Cost Ratio	5.21	5.16	5.09
Payback Time (years)	2	2	2

Source: Data compiled by author

The conclusion is that this action is also feasible.

5. Use of natural means for water purification

Zeolite-zinc (ZZ) minerals, with an appropiate technology act as purifier of water in a natural way. The action involves the installation of a factory to produce ZZ and filters for use in hotels, saving energy instead of using it for bottled water and adding an image of Green and Low-carbon tourist economy. The action is based on following assumptions:

- Implement cost = $ 6 million United States of America dollars (regarding a similar plant in Cuba)
- Energy saved: According to the current prices of the raw materials and energy, the production cost of one ton of ZZ would be $250 United States of America dollars. A comparison with the cost of the electric energy required for water boiling and disinfection or embotled water production --bearing in mind that a person's recommended daily consumption is 2-3 litres-- shows that without these ZZ systems $250 United States of America dollars would cover the water purifcation of up to 1900 persons in one day while the ZZ produced with the same resources could purify the water consumed in one day by 750,000 persons. Cost of Kw/h used = $ 0.066. It means $ 2 million United States of America dollars saved each year.
- Tourist data used: 1,5 million arrivals and 7 nights in destination.

Table 25: Benefit-cost ratio and net payback time at different discount rates for purification of water

	ZZ production		
Discount Rate	1%	2%	4%
Net Benefit-Net Cost Ratio	1.68	0.58	1.34
Payback Time (years)	8	8	9

Source: Data compiled by author

A deeper study is needed to start on this action.

VI. CONCLUSIONS

1. - The Bahamas is at great risk and vulnerability given its geographical features as a low-lying, sea encircled country. If projected sea level rise is reached by 2050, between 10-12% of territory will be lost, especially in coastal zones where the main tourism assets are located. Vulnerability could also be manifested if flight carbon emission taxes are established in the main source markets, representing an economic threat to the tourism sector for the islands.

2. – The impact of climate change on main tourism demand variables will cause some losses to the country's income and government revenues. This would be acting conjointly with some local threats to tourism assets and trends in future global tourism demand.

3. - The second and no less important threat is tropical cyclones, which may be associated with raising sea level. Estimations posited the amount of losses in excess of 2400 million US$ for the four decades under examination. It is to be pointed out that there is still a lack of comparatively accurate data collection and analysis on this subject, a point deserving more attention in order to deepen the understanding of, and to extract better lessons from these extreme events.

4. - In the same period, total estimated impacts of progressive climate change are between 17 and 19 billions of B$ with estimated discount rates applied.

5. - The Bahamas is a Small Island Developing State with low growth on GHG emissions (second in Latin America), as well as a relative short capacity to lower emissions in the future. The country has a relative delay in the application of renewable energy systems, a solution that, provided documented studies on-site, might turn out to be fundamental in the country's efforts to establish mitigation related policies.

6. - The Bahamas currently has institutions and organizations that deal with climate change-related issues and an important number of measures and courses of action have been set up by the government. Nevertheless, more coordination among them is needed and should include international institutions. This coordination is essential even for the first steps, i.e. to conduct studies with a bottom-up approach in order to draw more accurate programs on adaptation and mitigation.

7. - It is fundamental for tourism to keep track of potential losses in tourist attractions (and to act accordingly), related to correspondent losses in biodiversity, water resources and coastal erosion. Also, actions to fight climate change impacts might improve the islands security standards, quality of living and protect cultural and heritage assets. These elements may definitely shape the future of the country's competitiveness as a tourism destination.

8. – It is possible and necessary to decide about the options with good cost-benefit ratio and reasonable payback periods, notwithstanding that cost-benefit analysis requires more refined and accurate data to provide precise and locally adapted options.

ANNEX 1

IPCC Scenarios

Scenario Characteristics[c]							
Set	SRES						
Family	A1				A2	B1	B2
Scenario Group	A1C	A1G	A1B	A1T	A2	B1	B2
Population growth	low	low	low	low	high	low	medium
GDP growth	very high	very high	very high	very high	medium	high	medium
Energy use	very high	very high	very high	high	high	low	medium
Land-use changes	low-medium	low-medium	low	low	medium/high	high	medium
Resource Availability[d]	high	high	medium	medium	low	low	medium
Pace and direction of technological	rapid	rapid	rapid	rapid	slow	medium	medium
Change favoring	coal	oil & gas	balanced	non-fossils	regional	efficiency & dematerialization	"dynamic as usual"

ANNEX 2 – TOURISM CLIMATE INDEX

Quoted from:
Moore, Winston (2010). "The Impact of Climate Change on Caribbean Tourism Demand"

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

Table 1: Components of the Tourism Climate Index

Sub-Index	Variables	Influence on TCI	Weight
Daytime Comfort Index (CID)	Maximum daily temperature; Minimum daily relative humidity	Represents thermal comfort when maximum tourist activity occurs	40%
Daily Comfort Index (CIA)	Mean daily temperature; Mean daily relative humidity	Represents thermal comfort over the full 24 hour period, including sleeping hours	10%
Precipitation (P)	Total precipitation	Reflects the negative impact that this element has on outdoor activities and holiday enjoyment	20%
Sunshine (S)	Total hours of sunshine	Positive impact on tourism; (can be negative because of the risk of sunburn and added discomfort on hot days)	20%
Wind (W)	Average wind speed	Variable effect depending on temperature (evaporative cooling effect in hot climates rated positively, while wind chill in cold climates rated negatively)	10%

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

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

Table 2: Rating Categories for Tourism Climate Index

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

ANNEX 3

Neural Networks and Projections.

Artificial Neural Networks modeling, an artificial intelligence type of methods, with increasing presence in tourism demand studies (Mazanec 1992, Law and Au 1999, Law 2008, Wang 2004, Bigne and others, 2008, Delgado and Fernandez, 2010, Delgado and Abreu, 2010) was used for all the necessary projections in this paper. The ANN architectures employed were Multilayer Perceptron (MLP), Radial Basis Function (RBF) and Generalized Regression Neural Network (GRNN). A complete development on these artificial intelligence (AI) methods can be found in Luger and Stubblefield (1998) and also Montaño (2002) could be useful, apart from the cited applications. An important note on the performance of a network is placed here, to help the reader understand the forecast accuracy and possibilities of the ANNs. Network performance can be examined as network statistics can be generated including the mean and standard deviation of both the training data and the prediction error, with the latter value expected to be close to zero. However, it's always worth checking the value of the prediction error standard deviation. A ratio of the prediction error SD to the training data SD significantly below 1.0 indicates good regression performance, with a level below 0.1 often said (heuristically) to indicate excellent regression. One minus this ratio is sometimes referred to as the explained variance of the model. Other relevant statistics is the Pearson R (correlation coefficient), which can provide a way to compare the performance of the network with ordinary linear models. Nevertheless, usual error measures such as mean square error (MSE) and mean absolute percentage error (MAPE) among others are also included for each model. All the modeling was conducted in the statistical software Statistica Ver. 7.0 (Statsoft 2004). For a better understanding, the way to read the following line (only as an example):

Profile	MLP s7 1:7-8-8-1:1

This explains that a Multilayer Perceptron was employed, which had 7 nodes in the first layer, 8 nodes in the first hidden layer, 8 nodes in the second hidden layer and also naturally a single output node. This is explicitly stated in lines 6, 7 and 8.

ANNs work by dividing the data into three independent sets: Training, Selection and Test. Errors committed by the network are presented in lines 2, 3 and 4.

Training/Members (BP100, CG12b) is the code of optimization algorithms. In Statistica, codes for optimization methods are:

Statistica codes for ANN optimization methods

BP	Back Propagation
CG	Conjugate Gradient Descent
QN	Quasi-Newton
LM	Levenberg-Marquardt
QP	Quick Propagation
DD	Delta-Bar-Delta
SS	(sub)Sample
KM	K-Means (Center Assignment)
EX	Explicit (Deviation Assignment)
IS	Isotropic (Deviation Assignment)
KN	K-Nearest Neighbour (Deviation Assignment)
PI	Pseudo-Invert (Linear Least Squares Optimization)
KO	Kohonen (Center Assignment)
PN	Probabilistic Neural Network training
GR	Generalised Regression Neural Network training
PC	Principal Components Analysis

The terminal codes are:
b Best Network: the network with lowest selection error in the run was restored)
s Stopping Condition: the training run was stopped before the total number of epochs (iterations) elapsed as a stopping condition was fulfilled.
c Converged: the algorithm stopped early because it had converged; that is, reached and detected a local or global minimum. Note that only some algorithms can detect stoppage in a local minimum, and that this is an advantage not a disadvantage!

Thus, a line reading "(BP100, CG12b)" states: "There were used a variety of optimization algorithms, Back-Propagation (BP) with 100 epochs and Conjugate Gradient (CG) with 12 epochs of which the latter turned out to be the best (CG12**b**), i.e., the one determining a network which had the lowest error on selection set."
Statistics for the networks employed are listed below, divided into Stopovers, Cruises and Expenditures projection networks

Stopovers
BAU

Profile	GRNN 1:1-179-2-1:1
Train Error	0,000032
Select Error	0,000032
Test Error	0,000031
Training/Members	SS
Inputs	1
Hidden(1)	179
Hidden(2)	2
Data Mean	121840,3
Data S.D.	30512,7
Error Mean	717,1
Error S.D.	2987,8
S.D. Ratio	0,1
Mean square error	8932241,13
Mean absolute error	2416,50
Mean relative squared error	0,06
Mean relative absolute error	0,10
Mean absolute percentage error	9,787618658
Correlation coefficient	1,0

A2

Profile	RBF 2:2-12-1:1
Train Error	0,00
Select Error	0,00
Test Error	0,00
Training/Members	KM,KN,PI
Inputs	2,00
Hidden(1)	12,00
Hidden(2)	0,00
Data Mean	121840,27
Data S.D.	30512,74
Error Mean	-318,05
Error S.D.	1800,20
S.D. Ratio	0,06
Mean square error	856346264,00
Mean absolute error	23348,54
Mean relative squared error	0,06
Mean relative absolute error	0,16
Mean absolute percentage error	15,50
Correlation coefficient	0,96

	Monthly Air fuel cost (2008) prices	TCI A2
Rank.	2,000000	1,000000

B2

Profile	GRNN 2:2-179-2-1:1
Train Error	0,000031
Select Error	0,000036
Test Error	0,000033
Training/Members	SS
Inputs	2
Hidden(1)	179
Hidden(2)	2
Data Mean	121840,3
Data S.D.	30512,7
Error Mean	-248,2
Error S.D.	1403,8
S.D. Ratio	0,0
Mean square error	833266770
Mean absolute error	23083,0
Mean relative squared error	0
Mean relative absolute error	0

Mean absolute percentage error	11,16237363
Correlation coefficient	0,9

	Monthly Air fuel cost (2008) prices	TCI B2
Rank.	2,000000	1,000000

Cruises
BAU

Profile	GRNN 1:1-174-2-1:1
Train Error	0,000103
Select Error	0,000652
Test Error	0,000790
Training/Members	SS
Inputs	1
Hidden(1)	174
Hidden(2)	2
Data Mean	180436,5
Data S.D.	93624,0
Error Mean	-1336,8
Error S.D.	8215,7
S.D. Ratio	0,1
Mean square error	39587,61
Mean absolute error	25134,89
Mean relative squared error	0,00308
Mean relative absolute error	0,04
Mean absolute percentage error	3,81
Correlation coefficient	0,9

A2

Profile	GRNN 1:1-180-2-1:1
Train Error	0,000011
Select Error	0,000010
Test Error	0,000013
Training/Members	SS
Inputs	1
Hidden(1)	180
Hidden(2)	2
Data Mean	180088,696
Data S.D.	93723,753
Error Mean	207,041
Error S.D.	8320,435
S.D. Ratio	0,089
Mean square error	
Mean absolute error	69709,926
Mean relative squared error	0,020
Mean relative absolute error	0,110
Mean absolute percentage error	11,000
Correlation coefficient	0,970

	Monthly Diesel fuel cost (2008) prices	TCI A2
Rank.	1,000000	2,000000

B2

Profile	GRNN 1:1-409-2-1:1
Train Error	0,000007
Select Error	0,000006
Test Error	0,000006
Training/Members	SS
Inputs	1
Hidden(1)	409
Hidden(2)	2
Data Mean	265344,0
Data S.D.	101703,2
Error Mean	-116,2
Error S.D.	6304,8
S.D. Ratio	0,1
Mean square error	7479118197,94
Mean absolute error	64625,53
Mean relative squared error	0,02
Mean relative absolute error	0,03

Mean absolute percentage error		3,29
Correlation coefficient		1,0
	Monthly Diesel fuel cost (2008) prices	TCI B2
Rank.	2,000000	1,000000

Expenditures
BAU

Profile	RBF 6:6-7-1:1
Train Error	0,000139
Select Error	0,000408
Test Error	0,000191
Training/Members	KM,KN,PI
Inputs	6
Hidden(1)	7
Hidden(2)	0
Data Mean	1035,707
Data S.D.	524,324
Error Mean	-3,103
Error S.D.	48,998
S.D. Ratio	0,093
Mean square error	2921,160
Mean absolute error	38,665
Mean relative squared error	0,004
Mean relative absolute error	0,044
Mean absolute percentage error	4,444866787
Correlation coefficient	0,996

Variable	Rank.
Lodging Cap. (Rooms)	4,000000
Foreign Direct Investments (2008 mill)	3,000000
CPI BHS 2008 = 100	2,000000
CPI U.S. 2008 = 100	6,000000
GDP US (billions U$D) 2008	5,000000
Total Visitors (V) (Passengers) Thousands.	1,000000

A2

Profile	RBF 5:5-4-1:1
Train Error	0,000149
Select Error	0,000151
Test Error	0,000459
Training/Members	KM,KN,PI
Inputs	5
Hidden(1)	4
Hidden(2)	0
Data Mean	1035,707
Data S.D.	524,324
Error Mean	20,627
Error S.D.	63,242
S.D. Ratio	0,101
Mean square error	4425,065
Mean absolute error	43,554
Mean relative squared error	0,002
Mean relative absolute error	0,036
Mean absolute percentage error	3,641824767
Correlation coefficient	0,994

Variable	Rank.
Foreign Direct Investments (2008 mill)	2,000000
CPI BHS 2008 = 100	5,000000
CPI U.S. 2008 = 100	3,000000
GDP US (billions U$D) 2008	4,000000
Total Visitors (V) (Passengers) Thousands.	1,000000

B2

Profile	MLP 6:6-8-1:1
Train Error	0,025128
Select Error	0,011892
Test Error	0,028454
Training/Members	BP100,CG20,CG3b
Inputs	6
Hidden(1)	8
Hidden(2)	0
Data Mean	1035,707
Data S.D.	524,324
Error Mean	9,158
Error S.D.	55,443

S.D. Ratio	0,106
Mean square error	3157,751
Mean absolute error	43,296
Mean relative squared error	0,005
Mean relative absolute error	0,053
Mean absolute percentage error	5,255509279
Correlation coefficient	0,994

Variable	Rank.
Lodging Cap. (Rooms)	5,000000
Foreign Direct Investments (2008 mill)	1,000000
CPI BHS 2008 = 100	3,000000
CPI U.S. 2008 = 100	6,000000
GDP US (billions U$D) 2008	4,000000
Total Visitors (V) (Passengers) Thousands.	2,000000

ANNEX 4 – MITIGATION-ADAPTATION ACTIONS

	Travel Services - Strategies & Actions	Adapt.	Mitig.	Central Gov.	Local Gov.	Private Sector	NGOs & Community
1	Assess the impact of "emission taxes" considering the resilience of tourism demand.	X	X	X		X	
2	Negociate the "emission taxes" changing the base of calculation of taxes	X		X		X	
3	Determine Comfort Climate Index and its possible use in tourism trade	X		X	X		X
4	Risk transfer: propose an insurance for impacts of CC on tourists	X		X		X	
5	Stay informed about impending weather events	X			X	X	X
6	Follow guidance for emergency preparedness, and for conduct during and after an extreme weather event	X			X	X	X
7	Disseminate information on appropriate individual behavior to avoid exposure to vectors	X			X	X	X
8	Disseminate information on signs and symptoms of disease to guide individuals on when to seek treatment	X			X	X	X
9	Evaluate effects on logistics, adjust schedules when Time of travel on long distance flights and transoceanic shipping may be affected.	X				X	
10	Identify and improve evacuation routes in low-lying areas (e.g. causeways to coastal islands)	X			X	X	X
11	Implement early warning/notification systems for beach closures	X			X	X	X
12	Evaluate the possible introduction of exotic diseases and disease vectors, and their spread as a result of increases in mean temperature and humididy	X		X	X		
13	Identify climate change refuges for tourists, assess the optimal size, & acquire the necessary land. Use an insurance factor when calculating reserve sizes o account for uncertainty in CC	X			X	X	
14	Create or develop warning systems and emergency response plans, including appropriate individual behavior of tourists	X			X	X	
15	Elaborate market research to better estimate impacts on tourists	X		X	X	X	
16	Improve advertising campaigns offering new products and attractions	X		X	X	X	
17	If summer heat is high, upgraded air-conditioning, offer discounted room rates and establish hurricane interruption policy		X			X	
18	Increase offers of transportation by coach or ships, instead of airplanes or cars		X			X	X

	Hospitality Entities - Strategies & Actions	Adapt.	Mitig.	Central Gov.	Local Gov.	Private Sector	NGOs & Community
19	Establish a rule of obligation to use data collected and forecasts in proposals for decision making on investment (e.g. siting and design of facilities, environmental and risk assessment).	X		X	X	X	
20	To offer environmental and CC information to insurance companies	X		X	X	X	
21	Audit & CC retrofit programme for hotels and marinas	X			X	X	X
22	Checking preparedness of emergency planing & management of hurricane shelters for yachts & other recreational craft	X			X	X	
23	Prepare studies on risk transfers for hospitality entities	X		X	X	X	
24	Improve /implement Hospitality Entities Energy Solutions Programmes	X	X			X	
25	Implement Eco-label (green passport, etc) for tourist resorts	X		X		X	
26	Plant appropriate native (or, if necessary, introduced) desired species in hotel surrounding areas after disturbances or in anticipation of the loss of some species to maintain image of native nature	X				X	
27	Eliminate vector breeding sites around hospitality entities	X				X	X
28	Consider possible impacts of infrastructure development, such as water storage tanks, on vector-borne diseases	X		X	X	X	
29	Abandon/move threatened hotel rooms to higher elevations.	X				X	
30	Improve efficiency of energy use, especially electricity use e.g.: energy audits; contingency planning for probable seasonal electricity supply outages	X	X	X	X	X	
31	Diversify energy sources of tourist resorts to provide a more robust portfolio of options	X	X			X	
32	Prepare for supply interruptions, e.g. backup systems for emergency facilities	X		X	X	X	X
33	Improve storm readiness for marinas	X			X	X	
34	Establish marine debris reduction strategy	X			X	X	
35	Reinforce or relocate marinas harbor infrastructure	X		X	X		
36	Preparenedss for TC in staff training, water and food storage, ?rst aid kits for tourist assistance and trimming of trees	X				X	
37	Use more efficient and renewable energy in cooling, warm water, and lighting		X			X	
38	Increase in use of locally produced food will have a considerably smaller energy footprint, instead of imports.		X			X	
39	Implement more environmentally oriented restaurants		X			X	
40	Allowing hot food to cool before storing it in refrigerators and freezers		X			X	
41	Not over?lling refrigerators, as best cooling occurs when air can circulate		X			X	
42	Regular checking and cleaning of fans, condensers and compressors		X			X	
43	Ensuring doors ?t and close properly, and seals are in good condition		X			X	
44	Ensuring refrigerator compressor belts maintain proper tension		X			X	
45	Defrosting freezers frequently since frost build-ups reduce ef?ciency.		X			X	
46	Prepare a plan for stop using disposable packaging, for instance for soap and shampoo		X			X	
47	Prohibition to use CFC refrigerants		X	X			
48	Use of natural means for water purification for tourists, saving energy						

	Destinations - Strategies & Actions	Adapt.	Mitig.	Central Gov.	Local Gov.	Private Sector	NGOs & Community
49	Collecting Data: temperature, seasonal rainfall, hot and cool days per year, sunny days, tropical cyclones economic impacts, windspeed, site elevation and wave data, includying high-resolution topography and bathymetry, GIS, emissions and other technologies)	X		X	X		X
50	Educational programmes (Combined Environmental, Sustainability, CC and DRM) for workers and community	X		X	X	X	X
51	Research combined projects on impacts of CC, Environment and Disasters in touristic zones	X	X		X	X	X
52	Encouraging adaptive site-level project planing and design	X	X	X	X	X	
53	Abandon/move threatened airports to higher elevations.	X		X	X	X	X
54	Changes in public infrastructure siting	X		X	X		X
55	Determine detailed costs assessments necessary to inform future negotiations regarding adaptation assistance from the international community (research & business plan)	X		X	X	X	X
56	Risk transfer: insurance for government premises that bring services to tourists	X		X	X	X	
57	Build or enhance dikes, sea-wall, levees for protection	X			X	X	
58	Improve water resource monitoring, storage and distribution	X			X	X	X
59	Expand or initiate water metering and charging to encourage water conservation	X		X	X	X	X
60	Implementation of desalination using renewable power sources to assist with periods of water shortages.	X				X	
61	Support the assessment of wind potential to supply electric power.	X		X	X	X	X
62	Improve desalinization plants with renewable energy for using in touristic zones	X	X		X	X	X
63	Establish special protection for areas that support keystone processes or sensitive species that is used as touristic attraction	X		X	X		X
64	Identify & take early proactive action against non-native invasive species that respond to climate change, especially where they threaten native species or current ecosystem function.	X			X	X	X
65	Incorporate long-term monitoring into design & management changes to ensure they are responsive to changes in base conditions	X		X	X		
66	Restore or create coastal wetlands, barrier islands and other protective natural ecosystems that is using as attractions	X			X	X	X
67	Remove structures that harden the coastlines, impede natural regeneration of sediments & prevent natural inland migration of sand & vegetation in response to CC	X		X	X		X

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