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FINAL REPORT

Bahamas - Eleuthera

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Caribbean Climate Change, Tourism & Livelihoods: A sectoral approach to vulnerability and resilience
Water, Energy, Agriculture, Human Health, Biodiversity, Infrastructure and Settlement, Comprehensive Disaster Management

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1. INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), published in 2007, provides undisputable evidence that human activities are the major reason for the rise in greenhouse gas emissions and changes in the global climate system (IPCC, 2007a). Climate change will affect ecosystem services in ways that increase vulnerabilities with regard to food security, water supply, natural disasters, as well as human health. Notably, climate change is ongoing, with "observational evidence from all continents and oceans … that many natural systems are being affected by regional climate changes, particularly temperature increases" (IPCC, 2007b: 8). Observed and projected climate change will in turn affect socio-economic development (Global Humanitarian Forum, 2009; Stern, 2006), with some 300,000 deaths per year currently being attributed to climate change (Global Humanitarian Forum, 2009). Mitigation, to reduce the speed at which the global climate changes, as well as adaptation to cope with changes that are inevitable, are thus of great importance (Parry *et al.,* 2009).

The IPCC (2007: 30) notes that "warming of the climate system is unequivocal, as it is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level". Climate change has started to affect many natural systems, including hydrological systems (e.g., increased runoff and earlier spring peak discharge, warming of lakes and rivers affecting thermal structure and water quality), terrestrial ecosystems (e.g., earlier spring events including leaf-unfolding, bird migration and egg-laying, biodiversity decline, and poleward and upward shifts in the ranges of plants and animal species), as well as marine systems (e.g., rising water temperatures, changes in ice cover, salinity, acidification, oxygen levels and circulation, affecting shifts in the ranges and changes of algae, plankton and fish abundance).

The IPCC (2007b) also notes that small islands are particularly vulnerable to the effects of climate change, including sea-level rise and extreme events. Deterioration in coastal conditions is expected to affect fisheries and tourism, with sea-level rise being "expected to exacerbate inundation, storm surge, erosion and other coastal hazards, threatening vital infrastructure, settlements and facilities that support the livelihood of island communities" (IPCC, 2007b: 15). Climate change is projected to reduce water resources in the Caribbean to a point where these become insufficient to meet demand, at least in periods with low rainfalls (IPCC, 2007b). Together, these changes are projected to severely affect socio-economic development and well-being in the world (Stern, 2006), with the number of climate change related deaths expected to rise to 500,000 per year globally by 2020 (Global Humanitarian Forum, 2009). However, not all regions are equally vulnerable to climate change. The Caribbean needs to be seen as one of the most vulnerable regions, due to their relative affectedness by climate change, but also in terms of their capacity to adapt (Bueno *et al.,* 2008). This should be seen in the light of Dulal *et al.*'s (2009: 371) conclusion that:

> *"If the Caribbean countries fail to adapt, they are likely to take direct and substantial economic hits to their most important industry sectors such as tourism, which depends on the attractiveness of their natural coastal environments, and agriculture (including fisheries), which are highly climate sensitive sectors. By no incidence, these two sectors are the highest contributors to employment in the majority of these countries and significant losses or economic downturn attendant to inability to adapt to climate change will not increase unemployment but have potentially debilitating social and cultural consequences to communities."*

This report looks specifically at the consequences of climate change for those sectors that are of key importance in defining vulnerability (i.e., water quality and availability, energy, agriculture, biodiversity, human health and infrastructure and settlements).

2. CLIMATE MODELLING: Observed and Projected Changes in Climate at Eleuthera, The Bahamas

2.1 *Executive Summary*

- Observed mean annual **temperatures** over The Bahamas in gridded temperature observations have increased at an average rate of 0.11˚C per decade over the period 1960-2006.

- Annual mean temperature changes specifically for Eleuthera, simulated by Regional Climate Model (RCM), indicate increases of 2.6-2.8˚C by the 2080s under a higher emissions scenario (A2). The regional model differs in its seasonal projections when driven by the different General Circulation Models (GCM) – driven by HadCM3 a similar level of warming is projected throughout the year, whilst when driven by ECHAM4 there are more rapid rates of warming in JJA and SON than the rest of the year.

- GCM projections of **future rainfall** for The Bahamas span both overall increases and decreases, but tend towards decreases in most models. RCM projections of rainfall over Eleuthera indicate decreases in annual rainfall of -6 to -28mm per month (-9 to -14%) by 2080 under an A2 scenario. The projections from based on HadCM3 boundary conditions indicate considerably more extreme drying than when based on ECHAM4. This reflects the particularly dry conditions in the driving GCM whilst the majority of other driving GCMs would be expected to generate more modest drying or increases. The changes in seasonality in rainfall simulated by the RCM varies depending on the driving GCM. ECHAM4 driven model runs indicate the largest proportional decreases in MAM and JJA rainfall (around -35%) but increases of around 24% in SON. The HadCM3-driven run indicates large proportional decreases in rainfall in MAM, JJA and SON with the largest decreases in JJA (around -40% by the 2080s).

- Both the observed and projected changes in **wind speed** in the region are very uncertain. Observed mean marine wind speeds around The Bahamas have shown significantly increasing trends in all seasons between 1960 and 2006, but particularly in SON. Whilst GCMs indicate small increases in wind speeds over The Bahamas, RCM simulations generate both increases and decreases depending on the driving GCM.

- Observed **relative humidity** (RH) in The Bahamas has not shown a long-term trend over recent years. The model projections generally indicate increases in Relative Humidity over ocean surfaces and decreases over the land surface. The diverging projections of RH for land and ocean regions mean that it is difficult to determine the likely changes in coastal regions and very small islands. A small and narrow island such as Eleuthera, which has no ‘inland’ regions, is likely to experience the overall increases in Relative Humidity associated with marine regions.

- The number of **sunshine hours** per day has increased in DJF, MAM and JJA in observations over The Bahamas between 1981 and 2003. Both variants of the RCM indicate increases in the number of sunshine hours. Under driving data from HadCM3, the largest increases are seen in JJA and SON with only very small changes in DJF and MAM, whilst under ECHAM4 sunshine hours increase similarly throughout the year.

- **Sea-surface temperatures** (SSTs) from the HadSST2 gridded dataset do not indicate statistically significant trends in the waters of The Bahamas in recent decades. GCM projections indicate increases in sea-surface temperatures throughout the year. Projected increases range between +0.9˚C and +2.7˚C by the 2080s, across all three emissions scenarios.

- GCM projections indicate that **'hot' days and nights** that have occurred on 10% of days in the observed climate period might occur on 26-67% of days per year by the 2080s in The Bahamas. 'Cold' days and nights may reduce in frequency from 10% of days/nights in the observed period, to less than 4% by the 2080s. In some model projections, these events do not occur at all in The Bahamas by the 2050s.

- GCM projections span both overall decreases and increases in **rainfall extremes** (1- and 5-day maxima, and the proportion of total rainfall that falls in heavy events) in the future in The Bahamas, but tend towards decreases in MAM and JJA, and decreases in SON and DJF.

- North Atlantic **hurricanes and tropical storms** appear to have increased in intensity over the last 30 years, although there is still debate regarding whether this represents a long-term trend. Observed and projected increases in SSTs indicate potential for continuing increases in hurricane activity, and model projections (although still relatively primitive) indicate that this may occur through increases in intensity of events (including increases in near storm rainfalls and peak winds), but not necessarily though increases in frequency. RCM projections for the Caribbean indicate potential decreases in the frequency of tropical cyclone-like vortices under warming scenarios due to changes in wind shear.

- **Sea-level** rises of around 1.5 to 3 mm per year have been observed at tidal gauging stations around the Caribbean. Model projections are currently very uncertain regarding future rates of sea-level rise (SLR) due to difficulties in predicting the melt rates of the Greenland and Antarctic ice sheets. IPCC projections range between 0.18 to 0.56 m by 2100 under an A2 emissions scenario, whilst alternative scenarios based on accelerating ice sheet melt indicate increases of up to 1.45m.

- **Storm surge** heights will be increased by the underlying rise in sea-level. These increases are likely to be enhanced by any increases in hurricane and tropical storm intensity.

2.2 *Introduction*

We present a summary of climate change information for Eleuthera, The Bahamas, derived from a combination of recently observed climate data sources, and model projections of future climate from both a General Circulation Model (GCM) ensemble of 15 models and the Regional Climate Model (RCM), *PRECIS*.

For each of a number of climate variables (average temperature, average rainfall, average wind speed, relative humidity, sea-surface temperature, sunshine hours, extreme temperatures, and extreme rainfalls) the results of GCM multi-model projections under three emissions scenarios at the country scale, and RCM simulations from single model driven by two different GCMs for a single emissions scenario at the destination scale, are examined. Where available, observational data sources are drawn upon to identify changes that are already occurring in the climates at both the country and destination scale.

General Circulation Models (GCMs) provide global simulations of future climate under prescribed greenhouse gas scenarios. These models are proficient in simulating the large scale circulation patterns and seasonal cycles of the world's climate, but operate at coarse spatial resolution (grid boxes are typically around 2.5 degrees latitude and longitude). This limited resolution hinders the ability for the model to represent the finer scale characteristics of a region's topography, and many of the key climatic processes which determine its weather and climate characteristics. Over the Caribbean, this presents significant problems as most of the small islands are too small to feature as a land mass at GCM resolution.

Regional Climate Models (RCMS) are often nested in GCMs to simulate the climate at a finer spatial scale over a small region of the world, acting to 'downscale' the GCM projections and provide a better physical representation of the local climate of that region. RCMs enable the investigation of climate changes at a sub-GCM-grid scale, such as local changes at a tourist destination.

In this study, we use RCM simulations from PRECIS, driven by two different GCMs (ECHAM4 and HadCM3) to look at projected climate for those countries and destinations. Combining the results of GCM and RCM experiments allows us to make use of the high-resolution RCM projections in the context of the uncertainty margins that the 15-model GCM ensemble provides.

Our projections are based on the IPCC standard 'marker' scenarios – A2 (a 'high' emissions scenario), A1B (a medium high scenario, where emissions increase rapidly in the earlier part for the next century but then plateau in the second half) and B1 (a 'low' emissions scenario). We examine climate projections under all three scenarios from the multi-model GCM ensemble, but at present, results from the regional models are only available for scenario A2.

We also examine the potential changes in hurricane and tropical storm frequency and intensity, sea-level rise, and storm surge incidence. For these variables, we draw on existing material in the literature to assess the potential changes affecting this tourist destination.

A supplementary technical document describes the data sources and processing in further detail.

2.3 *Temperature*

Refer to www.caribsave.org for figures in supplementary information.

The Bahamas

Observations from gridded temperature datasets indicate that mean annual temperatures over The Bahamas have increased at an average rate of 0.11˚C per decade. The observed increases have been most rapid in the seasons JJA and SON at rates of 0.13 and 0.15˚C per decade, respectively.

General Circulation Model (GCM) projections from a 15-model ensemble indicate that The Bahamas can be expected to warm by 0.8 to 1.9˚C by the 2050s and 1.0-3.2˚C by the 2080s, relative to the 1970-1999 mean. Projected mean temperatures increase most rapidly in JJA and SON, and changes are similar throughout The Bahamas.

Regional Climate Model (RCM) projections based on two driving GCMs project annual mean changes that are around the centre of the 15-member GCM ensemble (2.7 to 2.8˚C by the 2080s under scenario A2), and should therefore be interpreted in the context of a wider range of model uncertainty than is indicated by the RCM projections alone.

The improved spatial resolution in the RCM allows the land mass of the larger islands in The Bahamas to be represented, whilst the region is represented only by 'ocean' grid boxes at GCM resolution. Land surfaces warm more rapidly than ocean due to their lower capacity to absorb heat energy, and we therefore see more rapid warming over the larger Islands in RCM projections than in GCMs. Many Islands of The Bahamas remain too small to be represented in the 50km resolution RCM and may therefore underestimate warming in these areas.

Eleuthera

Observed records available from Eleuthera's Harbour Island gauging station span only 1970 to 1983 and are of insufficient length to infer meaningful long-term trends.

RCM projections indicate change in mean annual temperature of 2.6 to 2.8˚C across the two variants of the model by the 2080s under scenario A2. The regional model differs in its seasonal projections when driven by the different GCMs – driven by HadCM3 a similar level of warming is projected throughout the year, whilst driven by ECHAM4 we see more rapid rates of warming in JJA and SON than the rest of the year.

Table 2.3-1: Observed and GCM ensemble projections of temperature change in The Bahamas

The Bahamas: Country Scale Changes in Temperature												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	***Median***	***Max***	***Min***	***Median***	***Max***	***Min***	***Median***	***Max***
	(˚C)	*(change in ˚C per decade)*		*Change in ˚C*			*Change in ˚C*			*Change in ˚C*		
Annual	25.3	0.11*	*A2*	0.4	**0.8**	1.0	0.9	**1.5**	1.8	2.1	**2.7**	3.2
			A1B	0.4	**0.7**	1.1	0.9	**1.6**	1.9	1.5	**2.2**	2.8
			B1	0.3	**0.7**	0.9	0.8	**1.1**	1.5	1.0	**1.4**	2.0
DJF	22.6	0.12	*A2*	0.3	**0.8**	0.9	0.4	**1.4**	1.8	1.9	**2.4**	3.3
			A1B	0.3	**0.6**	1.0	1.0	**1.4**	2.1	1.3	**2.0**	3.0
			B1	0.4	**0.6**	1.2	0.6	**1.1**	1.4	1.0	**1.3**	2.0
MAM	24.3	0.06	*A2*	0.3	**0.7**	1.1	0.7	**1.4**	2.1	2.0	**2.5**	3.0
			A1B	0.2	**0.6**	1.1	0.7	**1.4**	2.0	1.5	**2.2**	2.5
			B1	0.2	**0.6**	1.1	0.5	**1.1**	1.5	0.9	**1.5**	1.9
JJA	27.9	0.13*	*A2*	0.4	**0.7**	1.1	1.1	**1.6**	1.8	2.1	**2.8**	3.1
			A1B	0.4	**0.8**	1.3	1.0	**1.7**	1.9	1.6	**2.3**	2.8
			B1	0.3	**0.7**	1.0	0.9	**1.2**	1.5	1.0	**1.5**	2.0
SON	26.5	0.15*	*A2*	0.6	**0.8**	1.0	1.1	**1.6**	1.8	2.2	**2.8**	3.3
			A1B	0.5	**0.8**	1.1	1.0	**1.7**	2.0	1.7	**2.4**	3.1
			B1	0.5	**0.7**	0.9	0.7	**1.2**	1.6	1.2	**1.6**	2.2

Table 2.3-2: GCM ensemble and RCM projections of temperature change in The Bahamas under the A2 scenario

The Bahamas: GCM and RCM Temperature comparison under A2 emissions scenario		Projected Changes by 2080		
		Changes in ˚C		
Annual	**GCM Ensemble Range**	2.1	**2.7**	*3.2*
	RCM (Echam4)		**2.8**	
	RCM (HadCM3)		**2.7**	
DJF	**GCM Ensemble Range**	1.9	**2.4**	*3.3*
	RCM (Echam4)		**2.3**	
	RCM (HadCM3)		**2.8**	
MAM	**GCM Ensemble Range**	2.0	**2.5**	*3.0*
	RCM (Echam4)		**2.5**	
	RCM (HadCM3)		**2.7**	
JJA	**GCM Ensemble Range**	2.1	**2.8**	*3.1*
	RCM (Echam4)		**3.2**	
	RCM (HadCM3)		**2.7**	
SON	**GCM Ensemble Range**	2.2	**2.8**	*3.3*
	RCM (Echam4)		**3.2**	
	RCM (HadCM3)		**2.7**	

Table 2.3-3: Observed and RCM projected changes in Temperature at Eleuthera, The Bahamas

Eleuthera: Destination Scale Changes in Temperature	Observed Mean 1970-99	Observed Trend 1970-1983		Projected changes by the 2020s			Projected changes by the 2050s			Projected changes by the 2080s		
	(mm per month)	*(change in mm per decade)*		*Change in ˚C*			*Change in ˚ C*			*Change in ˚C*		
Annual	24.9		***Echam A2***	*0.6*	**0.6**	*0.6*	*1.3*	**1.3**	*1.4*	*2.7*	**2.7**	*2.8*
			Hadley A2							*2.6*	**2.7**	*2.8*
DJF	22.1		***Echam A2***	*0.2*	**0.3**	*0.3*	*0.9*	**1.0**	*1.0*	*2.1*	**2.2**	*2.3*
			Hadley A2							*2.6*	**2.8**	*3.0*
MAM	24.0		***Echam A2***	*0.5*	**0.6**	*0.6*	*1.1*	**1.1**	*1.1*	*2.4*	**2.4**	*2.5*
			Hadley A2							*2.5*	**2.7**	*2.8*
JJA	27.7		***Echam A2***	*0.7*	**0.7**	*0.8*	*1.5*	**1.5**	*1.6*	*3.1*	**3.1**	*3.1*
			Hadley A2							*2.5*	**2.6**	*2.7*
SON	26.4		***Echam A2***	*0.8*	**0.8**	*0.9*	*1.7*	**1.7**	*1.7*	*3.1*	**3.1**	*3.2*
			Hadley A2							*2.5*	**2.7**	*2.8*

2.4 *Mean Precipitation*

Refer to www.caribsave.org for figures in supplementary information.

The Bahamas

Gridded observations of rainfall in The Bahamas do not indicate any significant or consistent trends. There are, however, a number of particularly dry years that have occurred recently (2004, 2005 and 2006). The large inter-annual variability in rainfall in The Bahamas makes it difficult to extract long-term trends.

GCM projections of future rainfall for The Bahamas span both overall increases and decreases, but tend towards decreases in more models. Projected rainfall changes in annual rainfall range from -30 to +21 mm per month (-28% to +18%) by the 2080s across the three emissions scenarios.

The overall decreases in annual rainfall projected by GCMs occur largely through decreased MAM and JJA (early wet season) rainfall, but these decreases are offset by overall increases in SON rainfall (-26 to +63 mm per month, or -16 to +34% by 2080s). These increases in wet-season rainfall are greatest over the southern islands of The Bahamas.

RCM projections of rainfall for The Bahamas are strongly influenced by which driving GCM provides boundary conditions. Projections driven by ECHAM4 indicate decreases in MAM and JJA rainfall, offset by increases in SON rainfall and thus very little change in total annual rainfall. Driven by HadCM3, the seasonal pattern of change is very different, and projections indicate increases in the early season rainfalls (MAM, JJA) but substantial decreases in later season rainfall (SON). These HadCM3-driven projections correspond with those that are at the most extreme end of the range of GCM projections for drying in JJA and SON.

Eleuthera

Observed records available from Eleuthera's Harbour Island gauging station span only 1970 to 1983 and are of insufficient length to infer meaningful long-term trends.

RCM projections of rainfall over Eleuthera indicate decreases in annual rainfall of -6 to -28mm per month (-9 to -14%) by 2080 under scenario A2. The spatial variation in projected changes in surrounding grid-boxes is fairly large, such that the range of our projection values changes to -37mm per month to +1mm per month (-25% to 0%) when we consider neighbouring grid-boxes. The projections based on HadCM3 boundary conditions indicate considerably more extreme drying than when based on ECHAM4. This reflects the particularly dry conditions in the driving GCM whilst the majority of other driving GCMs would be expected to generate more modest drying or increases.

The changes in seasonality in rainfall simulated by the RCM vary depending on the driving GCMs. ECHAM4 driven model runs indicate the largest proportional decreases in MAM and JJA rainfall (around -35%) but increases of around 24% in SON. The HadCM3-driven run indicates large proportional decreases in rainfall in MAM, JJA and SON with the largest decreases in JJA (around -40% by the 2080s).

Table 2.4-1: Observed and GCM-ensemble-projected changes in Precipitation in The Bahamas.

The Bahamas: Country Scale Changes in Precipitation (mm)

	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(mm per month)	*(change in mm per decade)*		*Change in mm per month*			*Change in mm per month*			*Change in mm per month*		
Annual	99.3	0.6	*A2*	-7	**0**	8	-19	**-3**	15	-30	**-8**	12
			A1B	-15	**0**	7	-20	**-4**	10	-22	**-5**	21
			B1	-15	**-1**	12	-14	**-2**	7	-15	**0**	8
DJF	49.4	-0.9	*A2*	-11	**-3**	8	-16	**-2**	24	-19	**-2**	27
			A1B	-16	**-1**	18	-17	**-1**	17	-25	**-3**	13
			B1	-11	**0**	19	-14	**-2**	15	-15	**0**	16
MAM	84.4	3.1	*A2*	-16	**-3**	9	-21	**-10**	8	-28	**-17**	6
			A1B	-20	**-4**	9	-25	**-9**	8	-26	**-8**	2
			B1	-17	**-9**	5	-17	**-5**	16	-14	**-6**	0
JJA	142.1	0.7	*A2*	-14	**-2**	22	-38	**-11**	15	-55	**-21**	5
			A1B	-23	**-5**	26	-43	**-7**	19	-55	**-12**	14
			B1	-27	**-5**	12	-22	**-5**	4	-28	**-6**	16
SON	121.5	-0.2	*A2*	-16	**4**	31	-11	**3**	32	-26	**6**	34
			A1B	-14	**3**	22	-23	**5**	29	-16	**8**	63
			B1	-14	**6**	27	-31	**0**	35	-14	**7**	37

Table 2.4-2: GCM and RCM simulated changes in precipitation in The Bahamas.

The Bahamas: GCM and RCM Precipitation comparison under A2 emissions scenario				
			Projected Changes by ***2080***	
			Changes in mm	
Annual	**GCM Ensemble Range**	-30	**-8**	*12*
	RCM (Echam4)		**-2**	
	RCM (HadCM3)		**-16**	
DJF	**GCM Ensemble Range**	-19	**-2**	*27*
	RCM (Echam4)		**3**	
	RCM (HadCM3)		**7**	
MAM	**GCM Ensemble Range**	-28	**-17**	*6*
	RCM (Echam4)		**-26**	
	RCM (HadCM3)		**-1**	
JJA	**GCM Ensemble Range**	-55	**-21**	*5*
	RCM (Echam4)		**-12**	
	RCM (HadCM3)		**-51**	
SON	**GCM Ensemble Range**	-26	**6**	*34*
	RCM (Echam4)		**24**	
	RCM (HadCM3)		**-21**	

Table 2.4-3: Observed and RCM-projected changes in precipitation on Eleuthera, The Bahamas.

Eleuthera: Destination Scale Changes in Precipitation (mm)												
	Observed Mean 1970-99	**Observed Trend 1970-1983**			***Projected changes by the 2020s***			***Projected changes by the 2050s***			***Projected changes by the 2080s***	
	(mm per month)	*(change in mm per decade)*			*Change in mm*			*Change in mm*			*Change in mm*	
Annual	94.4		***Echam A2***	*-16*	**-9**	*-3*	*-13*	**-8**	*-2*	*-13*	**-6**	*1*
			Hadley A2							*-37*	**-28**	*-10*
DJF	50.9		***Echam A2***	*-35*	**-27**	*-15*	*-35*	**-28**	*-17*	*-18*	**-9**	*4*
			Hadley A2							*-11*	**3**	*24*
MAM	75.4		***Echam A2***	*-26*	**-16**	*-5*	*-20*	**-9**	*4*	*-41*	**-34**	*-24*
			Hadley A2							*-18*	**-8**	*9*
JJA	136.7		***Echam A2***	*-21*	**-14**	*-6*	*-12*	**-4**	*1*	*-18*	**-8**	*0*
			Hadley A2							*-70*	**-64**	*-48*
SON	118.3		***Echam A2***	*8*	**19**	*33*	*-1*	**7**	*19*	*10*	**27**	*42*
			Hadley A2							*-70*	**-43**	*0*

Table 2.4-4: Observed and GCM-ensemble simulated changes in precipitation (%) in The Bahamas.

The Bahamas: Country Scale Changes in Precipitation												
	Observed Mean 1970-99	**Observed Trend 1960-2006**			***Projected changes by the 2020s***			***Projected changes by the 2050s***			***Projected changes by the 2080s***	
				Min	***Median***	***Max***	***Min***	***Median***	***Max***	***Min***	***Median***	***Max***
	(mm per month)	*(change in % per decade)*			*% Change*			*% Change*			*% Change*	
Annual	99.3	0.6	*A2*	-10	**0**	7	-18	**-3**	12	-28	**-8**	10
			A1B	-14	**0**	6	-19	**-5**	9	-21	**-8**	18
			B1	-14	**-1**	10	-13	**-2**	6	-14	**0**	6
DJF	49.4	-1.8	*A2*	-19	**-4**	8	-16	**-3**	19	-18	**-2**	31
			A1B	-25	**-2**	24	-20	**-2**	20	-24	**-3**	17
			B1	-15	**0**	25	-16	**-3**	12	-15	**0**	18
MAM	84.4	3.7	*A2*	-20	**-5**	14	-34	**-15**	14	-46	**-23**	8
			A1B	-26	**-5**	16	-44	**-14**	13	-41	**-16**	4
			B1	-31	**-13**	8	-31	**-9**	26	-27	**-7**	0
JJA	142.1	0.5	*A2*	-13	**-2**	15	-35	**-13**	10	-50	**-21**	4
			A1B	-21	**-6**	17	-39	**-9**	17	-51	**-17**	13
			B1	-25	**-5**	11	-28	**-6**	3	-26	**-11**	11
SON	121.5	-0.2	*A2*	-16	**3**	18	-7	**2**	22	-16	**4**	24
			A1B	-9	**1**	11	-15	**3**	20	-10	**5**	34
			B1	-11	**4**	18	-20	**0**	28	-9	**4**	26

Table 2.4-5: GCM and RCM projected changes in precipitation (%) in The Bahamas.

The Bahamas: GCM and RCM Precipitation comparison under A2 emissions scenario			Projected Changes by *2080*	
			Changes in ˚%	
Annual	**GCM Ensemble Range**	-28	**-8**	*10*
	RCM (Echam4)		**-5**	
	RCM (HadCM3)		**-7**	
DJF	**GCM Ensemble Range**	-18	**-2**	*31*
	RCM (Echam4)		**3**	
	RCM (HadCM3)		**14**	
MAM	**GCM Ensemble Range**	-46	**-23**	*8*
	RCM (Echam4)		**-27**	
	RCM (HadCM3)		**-3**	
JJA	**GCM Ensemble Range**	-50	**-21**	*4*
	RCM (Echam4)		**-22**	
	RCM (HadCM3)		**-35**	
SON	**GCM Ensemble Range**	-16	**4**	*24*
	RCM (Echam4)		**23**	
	RCM (HadCM3)		**-7**	

Table 2.4-6: Observed and RCM-projected changes in precipitation (%) on Eleuthera, The Bahamas.

Eleuthera: Destination Scale Changes in Precipitation	Observed **Mean** 1970-99	Observed **Trend** 1970-1983		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
	(mm per month)	*(change in mm per decade)*		*Change in %*			*Change in %*			*Change in %*		
Annual	94.4		***Echam A2***	*-19*	**-13**	*-5*	*-14*	**-9**	*-2*	*-17*	**-9**	*-1*
			Hadley A2							*-25*	**-14**	*0*
DJF	50.9		***Echam A2***	*-28*	**-23**	*-14*	*-28*	**-24**	*-16*	*-15*	**-8**	*3*
			Hadley A2							*-5*	**12**	*34*
MAM	75.4		***Echam A2***	*-24*	**-13**	*0*	*-21*	**-10**	*6*	*-40*	**-35**	*-26*
			Hadley A2							*-23*	**-11**	*7*
JJA	136.7		***Echam A2***	*-44*	**-33**	*-17*	*-24*	**-10**	*3*	*-36*	**-19**	*-2*
			Hadley A2							*-48*	**-40**	*-30*
SON	118.3		***Echam A2***	*7*	**17**	*32*	*-2*	**6**	*16*	*9*	**24**	*39*
			Hadley A2							*-33*	**-15**	*5*

2.5 *Wind Speed*

Refer to www.caribsave.org for figures in supplementary information.

The Bahamas

Observed mean wind speeds from the ICOADS mean monthly marine surface wind dataset demonstrate significantly increasing trends in all seasons over the periods 1960-2006 over The Bahamas. Over the year, the increasing trend is 0.33 ms^{-1} per decade. The strongest trends are seen in SON, of 0.45 ms^{-1} per decade. The observed increase in Atlantic Hurricane/Tropical Storm activity (see section 2.11) is likely to have contributed to this strong trend in SON, but trends in other seasons indicate an underlying increase in mean wind speeds, regardless of changes in Hurricane frequency or intensity.

Mean wind speeds generally increase in GCM projections, but not as dramatically as in the observations of the last few decades. Projected changes range between -0.1 and +0.5 ms^{-1} by the 2080s. Projected increases are greatest in MAM, ranging between -0.1 and +1.1 ms^{-1} by the 2080s. Wind speeds in SON projections, by contrast to the observed data, do not show the least consistent or dramatic increases – wind speeds in projections in SON range between -0.5 and +0.6 ms^{-1}.

Whilst average wind speeds increase in GCM projections, the RCM projections give very mixed indications for The Bahamas. Driven by HadCM3, the RCM indicates increases in wind speeds in JJA only (+0.3ms^{-1}) and decreases throughout the rest of the year, with the largest decreases, 0.9 ms^{-1} by 2080, in SON. Driven by ECHAM4, the RCM simulates small increases in wind speed which correspond with mid-range changes from the GCM ensemble.

Eleuthera

RCM projections indicate changes of -0.3 to +0.1ms^{-1} in mean annual wind speeds on Eleuthera by the 2080s. Driven by ECHAM4, the model simulations indicate very little change in average wind speeds throughout the year, whilst HadCM3-driven simulations indicate substantial decreases through SON, DJF and MAM, with particularly large decreases of 1.1 ms^{-1} in SON.

Table 2.5-1: Observed and GCM-ensemble-projected changes in wind speeds in The Bahamas.

The Bahamas: Country Scale Changes in Wind Speed												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(ms^{-1})	*(change in ms^{-1} per decade)*		*Change in ms^{-1}*			*Change in ms^{-1}*			*Change in ms^{-1}*		
Annual	6.5	0.33*	*A2*	-0.1	**0.1**	0.2	-0.1	**0.0**	0.4	-0.1	**0.2**	0.5
			A1B	0.0	**0.0**	0.2	0.0	**0.1**	0.4	-0.1	**0.2**	0.4
			B1	-0.1	**0.0**	0.3	-0.1	**0.1**	0.1	0.0	**0.1**	0.2
DJF	7.2	0.37*	*A2*	-0.1	**0.0**	0.4	-0.7	**-0.1**	0.7	-0.3	**0.2**	0.5
			A1B	-0.1	**0.1**	0.3	-0.1	**0.1**	0.7	-0.1	**0.2**	0.4
			B1	-0.2	**-0.1**	0.1	-0.2	**0.1**	0.2	-0.4	**0.2**	0.5
MAM	6.5	0.23*	*A2*	-0.1	**0.1**	0.5	-0.2	**0.3**	0.8	0.1	**0.3**	1.1
			A1B	-0.2	**0.1**	0.6	-0.4	**0.0**	0.6	-0.1	**0.4**	0.9
			B1	-0.2	**0.2**	0.8	-0.1	**0.3**	0.4	-0.1	**0.4**	0.5
JJA	5.7	0.24*	*A2*	-0.2	**0.0**	0.3	-0.3	**0.0**	0.4	-0.4	**0.2**	0.7
			A1B	-0.2	**0.0**	0.3	-0.1	**0.1**	0.4	-0.2	**0.1**	1.1
			B1	-0.2	**0.1**	0.3	-0.3	**0.0**	0.4	-0.1	**0.2**	0.3
SON	6.5	0.45*	*A2*	-0.3	**0.0**	0.2	-0.2	**0.0**	0.3	-0.4	**0.0**	0.2
			A1B	-0.1	**-0.1**	0.4	-0.2	**0.1**	0.2	-0.5	**0.3**	0.6
			B1	-0.2	**0.0**	0.2	-0.3	**-0.1**	0.2	-0.2	**0.0**	0.0

Table 2.5-2: GCM and RCM projected changes in wind speed in The Bahamas.

The Bahamas: GCM and RCM Wind Speed comparison under A2 emissions scenario				
			Projected Changes by ***2080***	
			Changes in ms^{-1}	
	GCM Ensemble Range	-0.1	**0.2**	*0.5*
Annual	**RCM (Echam4)**		**0.1**	
	RCM (HadCM3)		**-0.3**	
	GCM Ensemble Range	-0.3	**0.2**	*0.5*
DJF	**RCM (Echam4)**		**0.1**	
	RCM (HadCM3)		**-0.5**	
	GCM Ensemble Range	0.1	**0.3**	*1.1*
MAM	**RCM (Echam4)**		**0.0**	
	RCM (HadCM3)		**-0.2**	
	GCM Ensemble Range	-0.4	**0.2**	*0.7*
JJA	**RCM (Echam4)**		**0.3**	
	RCM (HadCM3)		**0.3**	
	GCM Ensemble Range	-0.4	**0.0**	*0.2*
SON	**RCM (Echam4)**		**0.1**	
	RCM (HadCM3)		**-0.9**	

Table 2.5-3: Observed and RCM-projected changes in wind speed on Eleuthera, The Bahamas.

Eleuthera: Destination Scale Changes in Wind Speed												
	Observed **Mean** 1970-99	Observed **Trend** 1973-2008		***Projected changes by the 2020s***			***Projected changes by the 2050s***			***Projected changes by the 2080s***		
	(mm per month)	*(change in mm per decade)*		*Change in m s^{-1}*			*Change in m s^{-1}*			*Change in m s^{-1}*		
Annual			***Echam A2***				0.0	**0.1**	0.1	*0.0*	**0.1**	*0.1*
			Hadley A2							*-0.5*	**-0.4**	*-0.3*
DJF			***Echam A2***				0.0	**0.1**	0.2	*0.0*	**0.1**	*0.1*
			Hadley A2							*-0.6*	**-0.5**	*-0.3*
MAM			***Echam A2***				0.0	**0.1**	0.2	*-0.2*	**-0.1**	*0.1*
			Hadley A2							*-0.4*	**-0.3**	*-0.2*
JJA			***Echam A2***				0.1	**0.3**	0.4	*0.1*	**0.2**	*0.4*
			Hadley A2							*0.0*	**0.1**	*0.3*
SON			***Echam A2***				-0.4	**-0.3**	-0.1	*-0.1*	**0.0**	*0.1*
			Hadley A2							*-1.2*	**-1.1**	*-1.0*

2.6 *Relative Humidity*

Refer to www.caribsave.org for figures in supplementary information.

There is no significant trend in observations from the HadCRUH dataset (1973-2003).

Relative humidity (RH) data is not available for all models in the 15-model ensemble, but projections from those models that are available tend towards small increases in RH, particularly in DJF and MAM. However, the ensemble sub-sample range does span both increases and decreases in RH in all seasons.

Due to the coarse spatial resolution of GCMs, the land mass of the small islands of The Bahamas are not represented in these models and this exerts a strong influence on RH. Ocean and land surfaces respond differently to increases in temperature due to the availability of water. Over ocean surfaces, temperature increases cause increased evaporation of water from the surface. This not only distributes some of the excess heat, but also results in a higher volume of atmospheric water vapour, causing higher specific humidity, although not necessarily higher RH. Over the land surface, only a limited amount of water is available, and therefore increased temperatures will result in an increased *potential* for evaporation, and this potential increase will only be partially met by available surface moisture. This will result in a small increase in specific humidity, but a likely decrease in RH as the air temperature increases. The representation of the land surface in climate models therefore becomes very important when considering changes in RH under a warmer climate, and we see a substantial disparity between the changes projected for those Caribbean islands which appear in RCM simulations, but not GCMs. This has implications for interpreting projections from both the RCM and GCMs for the Bahamian islands that are too small to appear in RCMs.

RCM simulations generally indicate increases in RH in marine regions of The Bahamas, but decreases over the land areas of the larger islands. This distinction between the response of land and ocean surfaces is clear in RCM runs based on both ECHAM4 and HadCM3. When driven by ECHAM4, the RCM indicates overall decreases in RH in DJF, but increases in all but the land surface areas throughout the rest of the year. Conversely, when driven by HadCM3, the model indicates the largest increases in RH in DJF, and slight increases in JJA.

Eleuthera

The diverging projections of RH for land and ocean regions mean that it is difficult to determine the likely changes in coastal regions and very small islands such as Eleuthera. A small and narrow island such as Eleuthera, which has no ‘inland’ regions, is likely to experience the overall increases in RH associated with marine regions. The RCM projections indicate increases in mean annual RH of 0.8-0.9% by the 2080s under the A2 scenario, with a range of 0.2 to 1.4% when we consider neighbouring grid boxes. The seasonal changes differ between the projections from the RCM when driven by different GCMs. ECHAM4 driven projections indicate decreased RH in DJF (-1.0%), but increases throughout the year (1.1-2.2%), whilst driven by HadCM3 the largest increase occur in DJF (1.2 %) with only slight increases in JJA.

Table 2.6-1: Observed and GCM-ensemble simulated changes in relative humidity in The Bahamas.

The Bahamas: Country Scale Changes in Relative Humidity												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(%)	*(change in % per decade)*		*Change in %*			*Change in %*			*Change in %*		
			A2									
Annual	78.1	-0.05	*A1B*	0.0	**0.0**	0.1	-0.2	**0.5**	0.5	-0.7	**0.2**	0.8
			B1	-0.4	**0.0**	0.2	-0.4	**0.2**	0.4	-0.2	**0.1**	0.7
			A2									
DJF	77.3	0.42	*A1B*	-0.8	**0.3**	0.5	-0.4	**0.4**	1.6	-1.3	**0.1**	1.5
			B1	-1.6	**0.0**	1.1	-0.8	**-0.1**	1.0	-1.1	**-0.1**	0.4
			A2									
MAM	77.3	-0.12	*A1B*	-0.7	**-0.1**	0.1	-0.2	**0.1**	0.7	-0.3	**0.5**	1.9
			B1	-0.3	**-0.2**	0.9	-0.6	**0.5**	1.2	-0.6	**0.4**	0.8
			A2									
JJA	79.3	-0.23	*A1B*	-0.3	**0.2**	0.3	-0.9	**0.3**	0.6	-1.7	**-0.1**	1.0
			B1	-1.6	**-0.2**	0.3	-0.4	**0.1**	0.3	-1.1	**-0.2**	1.7
			A2									
SON	78.5	-0.24	*A1B*	0.2	**0.3**	0.7	-0.1	**0.6**	1.1	-0.7	**0.3**	0.8
			B1	0.1	**0.2**	0.7	-0.6	**0.2**	1.0	0.0	**0.5**	1.5

Table 2.6-2: Observed and RCM-simulated changes in relative humidity in Eleuthera, The Bahamas.

Eleuthera: Destination Scale Changes in Relative Humidity												
	Observed **Mean** 1970-99	Observed **Trend** 1973-2008		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
	(mm per month)	*(change in mm per decade)*		*Change in %*			*Change in %*			*Change in %*		
Annual			***Echam A2***	*-0.1*	**0.0**	*0.1*	*0.4*	**0.6**	*0.7*	*0.7*	**0.9**	*1.0*
			Hadley A2							*0.2*	**0.8**	*1.4*
DJF			***Echam A2***	*-1.6*	**-1.4**	*-1.1*	*-1.5*	**-1.3**	*-1.1*	*-1.2*	**-1.0**	*-0.9*
			Hadley A2							*0.4*	**1.2**	*1.9*
MAM			***Echam A2***	*1.0*	**1.2**	*1.3*	*1.1*	**1.3**	*1.4*	*1.8*	**2.2**	*2.5*
			Hadley A2							*0.5*	**1.1**	*1.7*
JJA			***Echam A2***	*-0.6*	**-0.3**	*-0.2*	*0.6*	**0.9**	*1.0*	*1.0*	**1.2**	*1.4*
			Hadley A2							*-0.4*	**0.1**	*0.7*
SON			***Echam A2***	*0.2*	**0.4**	*0.7*	*1.1*	**1.4**	*1.7*	*0.9*	**1.1**	*1.4*
			Hadley A2							*0.4*	**0.9**	*1.5*

2.7 *Sunshine Hours*

Refer to www.caribsave.org for figures in supplementary information.

The Bahamas

The number of 'sunshine hours' per day are calculated by applying the average clear-sky fraction from cloud observations to the number of daylight hours for the latitude of the location and the time of year. The observed number of sunshine hours based on ISCCP satellite observations of cloud coverage indicates statistically significant increases in sunshine hours over recent years (1983-2001) in all seasons except the wettest season, SON. In DJF, sunshine hours have increased by 0.83 hours per decade, and in JJA and MAM by 0.63 and 0.65 hours, respectively.

The number of sunshine hours is implied by most models to increase into the 21st century in The Bahamas, reflecting reductions in average cloud cover fractions, although the model ensemble spans both increases and decreases in all seasons and emissions scenarios. The changes in annual average sunshine hours are to span -0.1 to +1.2 hours per day by the 2080s across all three scenarios. The increases are largest in JJA, with changes of -0.2 to +1.6 hours per day by the 2080s.

Comparison between GCM and RCM projections of sunshine hours for The Bahamas shows the RCM simulations lie in the higher end of the range of GCM changes in sunshine hours at +0.7 to +0.9 compared with -0.2 to +1.0 in GCM ensemble. Both RCM simulations indicate the largest increase in sunshine hours in JJA, which is in agreement with the GCM ensemble.

Eleuthera

Projections from the RCM for Eleuthera indicate increases in annual average sunshine hours of +0.7 to +1.0 hours of sunshine per day by the 2080s under scenario A2. The uncertainty range on these projections is +0.4 to 1.1 when we consider the neighbouring grid boxes. Under driving data from HadCM3, the largest increases are seen in JJA and SON, with only very small changes in DJF and MAM. Similarly under ECHAM4, sunshine hours increased throughout the year.

Table 2.7-1: Observed and GCM-ensemble-projected changes in the number of sunshine hours per day in The Bahamas.

The Bahamas: Country Scale Changes in Sunshine Hours												
	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(hrs)	*(change in hrs per decade)*		*Change in hrs*			*Change in hrs*			*Change in hrs*		
Annual	5.6	0.50*	*A2*	-0.1	**0.1**	0.5	0.0	**0.3**	0.7	0.0	**0.5**	1.0
			A1B	-0.2	**0.1**	0.3	-0.1	**0.3**	0.6	0.0	**0.4**	1.2
			B1	-0.2	**0.2**	0.4	-0.1	**0.1**	0.7	-0.1	**0.2**	0.9
DJF	5.6	0.83*	*A2*	0.0	**0.2**	0.4	-0.1	**0.3**	0.8	-0.5	**0.3**	1.3
			A1B	-0.3	**0.1**	0.4	-0.2	**0.3**	0.7	-0.3	**0.3**	1.4
			B1	-0.2	**0.2**	0.3	-0.3	**0.1**	0.6	-0.2	**0.1**	0.6
MAM	6.1	0.65*	*A2*	-0.4	**0.1**	0.6	-0.2	**0.4**	1.0	-0.2	**0.5**	1.3
			A1B	-0.3	**0.2**	0.5	-0.4	**0.3**	0.8	-0.3	**0.5**	1.2
			B1	-0.6	**0.2**	0.8	-0.5	**0.1**	0.6	-0.1	**0.1**	1.0
JJA	5.8	0.63*	*A2*	-0.4	**0.1**	0.6	-0.1	**0.5**	1.0	-0.1	**0.9**	1.5
			A1B	-0.3	**0.1**	0.5	0.1	**0.4**	0.8	0.2	**0.9**	1.6
			B1	-0.2	**0.2**	0.6	-0.4	**0.3**	1.0	-0.2	**0.4**	1.3
SON	4.7	0.05	*A2*	-0.2	**0.2**	0.7	-0.2	**0.1**	0.5	-0.4	**0.3**	0.8
			A1B	-0.7	**0.1**	0.3	-0.3	**0.1**	0.4	-0.2	**0.4**	0.7
			B1	-0.3	**0.0**	0.4	-0.2	**0.2**	0.5	-0.5	**0.0**	0.6

Table 2.7-2: GCM and RCM projected changes in the number of sunshine hours per day in The Bahamas.

The Bahamas: GCM and RCM Sunshine Hours comparison under A2 emissions scenario		Projected Changes by 2080		
		Changes in hrs		
Annual	**GCM Ensemble Range**	-0.2	0.5	1
	RCM (Echam4)		0.9	
	RCM (HadCM3)		0.7	
DJF	**GCM Ensemble Range**	-0.5	0.3	1.3
	RCM (Echam4)		0.7	
	RCM (HadCM3)		0.5	
MAM	**GCM Ensemble Range**	-0.2	0.5	1.3
	RCM (Echam4)		0.9	
	RCM (HadCM3)		0.2	
JJA	**GCM Ensemble Range**	-0.6	0.9	1.5
	RCM (Echam4)		1.7	
	RCM (HadCM3)		1.6	
SON	**GCM Ensemble Range**	-0.4	0.3	0.8
	RCM (Echam4)		0.6	
	RCM (HadCM3)		0.8	

Table 2.7-3: Observed and RCM-projected changes in the number of sunshine hours per day on Eleuthera, The Bahamas.

Eleuthera: Destination Scale Changes in Sunshine Hours	Observed Mean 1970-99	Observed Trend 1973-2008		Projected changes by the 2020s			Projected changes by the 2050s			Projected changes by the 2080s		
	(mm per month)	*(change in mm per decade)*		*Change in hrs*			*Change in hrs*			*Change in hrs*		
Annual			***Echam A2***	*-0.1*	**0.0**	*0.2*	*0.4*	**0.5**	*0.6*	*0.9*	**1.0**	*1.1*
			Hadley A2							*0.4*	**0.7**	*0.9*
DJF			***Echam A2***	*-0.2*	**0.1**	*0.3*	*0.2*	**0.4**	*0.6*	*0.6*	**0.8**	*1.0*
			Hadley A2							*0.1*	**0.3**	*0.7*
MAM			***Echam A2***	*-0.4*	**-0.2**	*0.1*	*0.4*	**0.6**	*0.8*	*0.6*	**0.9**	*1.0*
			Hadley A2							*-0.2*	**0.1**	*0.4*
JJA			***Echam A2***	*0.3*	**0.6**	*0.9*	*0.7*	**0.9**	*1.2*	*1.5*	**1.8**	*2.0*
			Hadley A2							*1.0*	**1.4**	*1.7*
SON			***Echam A2***	*-0.6*	**-0.4**	*-0.1*	*-0.1*	**0.2**	*0.4*	*0.4*	**0.7**	*0.9*
			Hadley A2							*0.5*	**0.9**	*1.3*

2.8 *Sea Surface Temperatures*

Refer to www.caribsave.org for figures in supplementary information.

Sea-surface temperatures from the HadSST2 gridded dataset do not indicate statistically significant trends in the waters of The Bahamas.

GCM projections indicate increases in sea-surface temperatures throughout the year. Projected increases range between +0.9˚C and +2.7˚C by the 2080s, across all three emissions scenarios. Increases tend to be fractionally higher in SON than in other seasons (1.0 to 2.9˚C by 2080). The range of projections under single emissions scenario spans around 1.0 to 1.5˚C.

Table 2.8-1: Observed and GCM-ensemble projected changes in sea surface temperatures in The Bahamas.

The Bahamas: Country Scale Changes in Sea Surface Temperatures

	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	(˚C)	*(change in ˚C per decade)*		*Change in ˚C*			*Change in ˚C*			*Change in ˚C*		
Annual	26.8	0.03	*A2*	0.4	**0.7**	0.9	0.8	**1.4**	1.7	1.9	**2.5**	2.7
			A1B	0.4	**0.6**	0.8	0.8	**1.5**	1.7	1.4	**2.2**	2.5
			B1	0.3	**0.5**	0.9	0.7	**1.1**	1.2	0.9	**1.4**	1.8
DJF	25.1	0.04	*A2*	0.3	**0.7**	0.9	0.6	**1.3**	1.7	1.8	**2.4**	2.8
			A1B	0.5	**0.5**	0.7	0.9	**1.3**	1.7	1.3	**2.3**	2.5
			B1	0.4	**0.5**	0.9	0.6	**1.0**	1.2	1.0	**1.2**	1.8
MAM	25.4	0.02	*A2*	0.2	**0.6**	0.9	0.6	**1.2**	1.8	1.8	**2.3**	2.6
			A1B	0.3	**0.5**	0.7	0.7	**1.3**	1.7	1.3	**2.2**	2.3
			B1	0.2	**0.5**	0.9	0.7	**0.9**	1.1	0.9	**1.5**	1.6
JJA	28.5	0.04	*A2*	0.4	**0.7**	0.9	1.2	**1.4**	1.8	1.9	**2.5**	2.9
			A1B	0.3	**0.7**	0.8	0.8	**1.5**	1.7	1.4	**2.2**	2.6
			B1	0.2	**0.6**	0.8	0.9	**1.0**	1.2	0.9	**1.5**	1.7
SON	28	0.04	*A2*	0.5	**0.7**	1.0	1.0	**1.5**	1.6	2.0	**2.6**	2.9
			A1B	0.3	**0.8**	0.9	0.9	**1.6**	1.7	1.6	**2.3**	2.8
			B1	0.4	**0.6**	0.9	0.7	**1.1**	1.3	1.0	**1.4**	2.0

2.9 *Temperature Extremes*

Refer to www.caribsave.org for figures in supplementary information.

'Extreme' hot or cold values are defined by the temperatures that are exceeded on 10% of days in the 'current' climate or reference period. This allows us to define 'hot' or 'cold' relative to the particular climate of a specific region or season, and determine changes in extreme events relative to that location.

The available observed daily data is insufficient to determine long-term trends in temperature extremes, but the data does indicate increases in 'hot' days and nights, and decreases in 'cold' days and nights during the period 1973-2008.

GCM projections indicate increases in the frequency of 'hot' days and nights, with their occurrence reaching 26-67% of days annually by the 2080s. The rate of increase varies substantially between models for each scenario, such that under A2 the most conservative increases result in frequency of 36% by the 2080s, with other models indicating frequencies as high as 67%.

Those days/nights that are considered 'hot ' for their season are projected to increase most rapidly in JJA, occurring on 50 to 99% of days in JJA by the 2080s.

Cold days/nights occur on a maximum of 4% of days/nights by the 2080s, and do not occur at all in projections from some models by the 2050s. Cold days/nights decrease in frequency most rapidly in JJA.

Table 2.9-1: Observed and GCM-ensemble-projected changes in temperature extremes in The Bahamas.

	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
	% Frequency	*Change in frequency per decade*						*Future % frequency*			*Future % frequency*	
Frequency of Hot Days (TX90p)												
			A2				26	**41**	47	36	**59**	67
Annual	12.0	2.33	*A1B*				28	**39**	45	32	**49**	61
			B1				24	**32**	38	26	**38**	45
			A2				37	**50**	66	61	**77**	90
DJF	11.4	8.01	*A1B*				41	**51**	64	46	**69**	85
			B1				30	**35**	49	32	**50**	68
			A2				26	**48**	67	47	**75**	91
MAM	12.0	7.4	*A1B*				31	**48**	64	46	**68**	85
			B1				22	**36**	41	22	**45**	67
			A2				57	**74**	85	78	**96**	99
JJA	11.3	5.83	*A1B*				56	**73**	81	69	**93**	98
			B1				48	**57**	65	49	**72**	83
			A2				33	**66**	82	53	**89**	97
SON	10.2	3.06	*A1B*				36	**69**	81	41	**87**	93
			B1				27	**54**	72	35	**63**	79
Frequency of Hot Nights (TN90p)												
			A2				32	**40**	47	44	**58**	66
Annual	10.4	1.96	*A1B*				33	**39**	44	39	**49**	60
			B1				28	**33**	38	31	**38**	45
			A2				32	**43**	59	54	**71**	84
DJF	12.0	2.11	*A1B*				37	**46**	57	44	**61**	78
			B1				29	**33**	45	30	**42**	62
			A2				32	**43**	65	58	**71**	89
MAM	11.6	0.34	*A1B*				29	**46**	62	54	**64**	83
			B1				27	**34**	39	28	**42**	60
			A2				71	**75**	86	87	**97**	99
JJA	10.8	9.41	*A1B*				70	**77**	82	82	**94**	98
			B1				52	**61**	64	61	**73**	82
			A2				50	**68**	81	73	**88**	96
SON	13.3	6.22	*A1B*				53	**68**	79	62	**86**	92
			B1				40	**56**	68	49	**63**	76
Frequency of Cold Days (TX10p)												
			A2				0	**4**	5	0	**1**	2
Annual	10.9	-0.81	*A1B*				0	**3**	4	0	**1**	3
			B1				1	**4**	6	1	**3**	4
			A2				0	**2**	5	0	**0**	1
DJF	10.7	-1.64	*A1B*				0	**2**	4	0	**1**	3
			B1				0	**3**	6	0	**3**	3
			A2				0	**2**	4	0	**0**	2
MAM	13.5	3.17	*A1B*				0	**2**	3	0	**1**	2
			B1				0	**4**	6	0	**3**	3
			A2				0	**0**	2	0	**0**	0
JJA	10.3	1.35	*A1B*				0	**0**	1	0	**0**	1
			B1				0	**0**	1	0	**0**	3
			A2				0	**1**	2	0	**0**	1
SON	13.6	-0.4	*A1B*				0	**1**	3	0	**0**	1
			B1				0	**2**	4	0	**2**	3
Frequency of Cold Nights (TN10p)												
			A2				1	**4**	5	0	**1**	2
Annual	10.1	-2.46	*A1B*				1	**3**	5	0	**2**	3
			B1				2	**4**	6	1	**3**	4
			A2				0	**3**	5	0	**0**	1
DJF	12.2	-3.61	*A1B*				0	**2**	4	0	**1**	2
			B1				1	**2**	7	0	**2**	3
			A2				0	**2**	6	0	**0**	1
MAM	10.7	5.46	*A1B*				1	**2**	4	0	**1**	2
			B1				1	**3**	6	1	**2**	4
			A2				0	**0**	0	0	**0**	0
JJA	10.4	-1.06	*A1B*				0	**0**	0	0	**0**	0
			B1				0	**0**	0	0	**0**	1
			A2				0	**1**	3	0	**0**	2
SON	10.4	-2.81	*A1B*				0	**2**	4	0	**0**	2
			B1				1	**3**	5	0	**2**	4

2.10 *Rainfall Extremes*

Refer to www.caribsave.org for figures in supplementary information.

Changes in rainfall extremes based on peal 1- and 5-day rainfall totals, as well as exceedance of a relative threshold for ‘heavy’ rain, were examined. ‘Heavy’ rain is determined by the daily rainfall totals that are exceeded on 5% of wet days in the ‘current’ climate or reference period, relative to the particular climate of a specific region or season.

Observations do not indicate statistically significant trends in any of the parameters over The Bahamas. There is large inter-annual variability in these measures of extreme rainfall and the available observed records are not sufficiently long to identify long-term trends.

GCM projections of rainfall extremes are mixed across the ensemble, ranging across both decreases and increases in all measures of extreme rainfall. However, the models projections do tend towards decreases in rainfall extremes in MAM and JJA and small increases in SON and DJF. The range of changes in the proportion of annual rainfall during heavy events is -4 to +6% by the 2080s across all emissions scenarios and the range of changes in 5-day maxima spans -12mm to +8mm by the 2080s.

Table 2.10-1: Observed and GCM-ensemble-projected changes in rainfall extremes in The Bahamas.

	Observed **Mean** 1970-99	Observed **Trend** 1960-2006		*Projected changes by the* ***2020s***			*Projected changes by the* ***2050s***			*Projected changes by the* ***2080s***		
				Min	*Median*	*Max*	*Min*	*Median*	*Max*	*Min*	*Median*	*Max*
% total rainfall falling in Heavy Events (R95pct)												
	%	*Change in % per decade*					*Change in %*			*Change in %*		
Annual	25.3	1.45	*A2*				-5	**0**	5	-4	**0**	6
			A1B				-4	**0**	5	-4	**0**	4
			B1				-4	**0**	4	-3	**1**	4
DJF			*A2*				-5	**0**	12	-8	**3**	15
			A1B				-9	**0**	11	-6	**1**	12
			B1				-6	**0**	6	-7	**2**	9
MAM			*A2*				-15	**-5**	4	-18	**-6**	5
			A1B				-20	**-4**	6	-14	**-6**	2
			B1				-12	**-3**	5	-12	**-2**	5
JJA			*A2*				-8	**-2**	8	-19	**-5**	6
			A1B				-9	**-3**	8	-10	**-4**	6
			B1				-7	**-1**	5	-10	**0**	7
SON			*A2*				-6	**1**	7	-5	**0**	10
			A1B				-4	**2**	6	-5	**-2**	8
			B1				-4	**0**	6	-2	**0**	6
Maximum 1-day rainfall (RX1day)												
	Mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
Annual	191.7	-0.28	*A2*				-3	**0**	7	-3	**1**	8
			A1B				-4	**0**	9	-12	**0**	8
			B1				-4	**0**	7	-2	**0**	8
DJF	86.6	17.47	*A2*				-4	**0**	9	-4	**2**	10
			A1B				-6	**0**	12	-1	**0**	11
			B1				-3	**-1**	3	-2	**1**	6
MAM	95.1	23.04	*A2*				-5	**-2**	3	-7	**-2**	3
			A1B				-7	**0**	5	-10	**-2**	1
			B1				-6	**-1**	4	-8	**0**	2
JJA	195.7	-39.47	*A2*				-5	**-1**	5	-6	**-2**	5
			A1B				-6	**-1**	2	-6	**-1**	2
			B1				-2	**0**	7	-8	**-1**	7
SON	83.4	20.43	*A2*				-2	**0**	9	-5	**1**	7
			A1B				-2	**1**	9	-8	**0**	6
			B1				-5	**0**	8	-2	**0**	10
Maximum 5-day Rainfall (RX5day)												
	Mm	*Change in mm per decade*					*Change in mm*			*Change in mm*		
Annual	146.1	-26.25	*A2*				-9	**0**	18	-9	**2**	25
			A1B				-7	**0**	19	-17	**-3**	16
			B1				-10	**0**	17	-5	**2**	26
DJF	52.9	7.68	*A2*				-7	**-2**	9	-11	**1**	17
			A1B				-13	**0**	16	-7	**0**	12
			B1				-8	**-1**	4	-4	**2**	13
MAM	53.9	9.14	*A2*				-14	**-4**	12	-21	**-6**	7
			A1B				-12	**-5**	6	-17	**-6**	4
			B1				-18	**-1**	5	-12	**-2**	6
JJA	124.1	-30.76	*A2*				-9	**-2**	20	-19	**-7**	13
			A1B				-12	**-4**	9	-11	**-5**	13
			B1				-6	**-2**	14	-21	**-2**	18
SON	57.4	21.86	*A2*				-5	**3**	21	-16	**3**	14
			A1B				-4	**5**	21	-17	**-4**	13
			B1				-8	**0**	19	-8	**2**	19

2.11 *Hurricanes and Tropical Cyclones*

Historical and future changes in tropical cyclone and hurricane activity have been a topic of heated debate in the climate science community. Drawing robust conclusions with regards to changes in climate extremes is continually hampered by issues of data quality in observations, the difficulties in separating natural variability from long-term trends and the limitations imposed by spatial resolution of climate models.

Tropical cyclones and hurricanes form from pre-existing weather disturbances where sea surface temperatures (SSTs) exceed 26˚C. Whilst SSTs are a key factor in determining the formation, development, and intensity of tropical cyclones, a number of other factors are also critical, such as subsidence, wind shear and static stability. This means that whilst observed and projected increases in SSTs under a warmer climate potentially expand the regions and periods of time when tropical cyclones may form, the critical conditions for storm formation may not necessarily be met (e.g., Vecchi and Soden, 2007; Trenberth *et al.*, 2007), and increasing SSTs may not necessarily be accompanied by an increase in the frequency of tropical storm incidences.

Several analyses of global (e.g., Webster *et al.*, 2005) and more specifically North Atlantic (e.g., Holland and Webster, 2007; Kossin *et al.*, 2007; Elsner *et al.,* 2008) hurricanes have indicated increases in the observed record of tropical cyclones over the last 30 years. It is not yet certain to what degree this trend arises as part of a long-term climate change signal or shorter-term interdecadal variability. The available longer term records are riddled with inhomogeneities (inconsistencies in recording methods through time) - most significantly, the advent of satellite observations, before which cyclones were only recorded when making landfall or observed by ships (Kossin *et al.*, 2007). Recently, a longer-term study of variations in hurricane frequency in the last 1500 years, based on proxy reconstructions from regional sedimentary evidence, indicate recent levels of Atlantic hurricane activity are anomalously high relative to those of the last one-and -a -half millennia (Mann *et al.*, 2009).

Climate models are still relatively primitive with respect to representing tropical cyclones, and this restricts our ability to determine future changes in frequency or intensity. We can analyse the changes in background conditions that are conducive to storm formation (i.e., boundary conditions) (e.g., Tapiador, 2008), or apply them to embedded high-resolution models which can credibly simulate tropical cyclones (e.g., Knutson and Tuleya, 2004; Emanuel *et al.*, 2008). Regional Climate Models are able to simulate weak ‘cyclone-like’ storm systems that are broadly representative of a storm or hurricane system but are still considered coarse in scale with respect to modelling hurricanes.

The IPCC AR4 (Meehl *et al.*, 2007a) concludes that models are broadly consistent in indicating increases in precipitation intensity associated with tropical cyclones (e.g., Knutson and Tuleya, 2004; Knutson *et al.*, 2008; Chauvin *et al.*, 2006; Hasegawa and Emori, 2005; Tsutsui, 2002). The higher resolution models that simulate cyclones more credibly are also broadly consistent in indicating increases in associated peak wind intensities and mean rainfall (Knutson and Tuleya, 2004; Oouchi *et al.*, 2006). We summarise the projected changes in wind and precipitation intensities from a selection of these modelling experiments in Table 2.11-1 to give an indication of the magnitude of these changes.

With regards to the ***frequency*** of tropical cyclones in future climate, models are strongly divergent. Several recent studies (e.g., Vecchi and Sodon, 2007; Bengtssen *et al.*, 2007; Emanuel *et al.*, 2008; Knutson *et al.*, 2008) have indicated that the frequency of cyclones may reduce due to decreases in vertical wind shear in a warmer climate. In several of these studies, intensity of hurricanes still increases despite decreases in frequency (Emanuel *et al.*, 2008; Knutson *et al.*, 2008). In a recent study of the *PRECIS* regional climate model simulations for Central America and the Caribbean, Bezanilla *et al.*, (2009) found that the frequency of ‘Tropical -Cyclone-Like –Vortices’ increases on the Pacific coast of Central America, but decreases on the Atlantic coast and in the Caribbean.

When interpreting the modelling experiments we should remember that our models remain relatively primitive with respect to the complex atmospheric processes that are involved in hurricane formation and development. Hurricanes are particularly sensitive to some of the elements of climate physics that these models are weakest at representing, and are often only included by statistical parameterisations. Comparison studies have demonstrated that the choice of parameterisation scheme can exert a strong influence on the results of the study (e.g., Yoshimura *et al.*, 2006). We should also recognise that the El Niño Southern Oscillation (ENSO) is a strong and well established influence on Tropical Cyclone frequency in the North Atlantic, and explains a large proportion of inter-annual variability in hurricane frequency. This means that the future frequency of hurricanes in the North Atlantic is likely to be strongly dependent on whether the climate state becomes more ‘El-Niño-Like’, or more ‘La-Niña-like’ – an issue upon which models are still strongly divided and suffer from significant deficiencies in simulating the fundamental features of ENSO variability (e.g., Collins *et al.*, 2005).

Table 2.11-1: Changes in Near-storm rainfall and wind intensity associated with Tropical cyclones in under global warming scenarios.

Reference	GHG scenario	Type of Model	Domain	Change in near-storm rainfall intensity	Change in peak wind intensity
Knutson *et al.* (2008)	A1B	Regional Climate Model	Atlantic	(+37, 23, 10)% when averaged within 50, 100 and 400km of the storm centre	+2.9%
Knutson and Tuleya (2004)	1% per year CO2 increase	9 GCMs + nested regional model with 4 different moist convection schemes.	Global	+12-33%	+5-7%
Oouchi *et al.* (2006)	A1B	High Resolution GCM	Global	N/A	+14%
			North Atlantic		+20%

2.12 *Sea Level Rise*

Observed records of sea level from tidal gauges and satellite altimeter readings indicate a global mean sea-level rise of 1.8 (+/- 0.5) mm yr^{-1} over the period 1961-2003 (Bindoff *et al.*, 2007). Acceleration in this rate of increase over the course of the 20th century has been detected in most regions (Woodworth *et al.*, 2009; Church and White, 2006).

There are large regional variations superimposed on the mean global sea-level rise rate. Observations from tidal gauges surrounding the Caribbean basin (Table 2.12-1) indicate that sea-level rise in the Caribbean is broadly consistent with the global trend (Table 2.12-2).

Table 2.12-1: Sea-level rise rates at observation stations surrounding the Caribbean Basin (NOAA, 2009).

Tidal Gauge Station	**Observed trend** (mm yr^{-1})	**Observation period**
Bermuda	2.04 (+/- 0.47)	1932-2006
San Juan, Puerto Rico	1.65 (+/- 0.52)	1962-2006
Guantanamo Bay, Cuba	1.64 (+/- 0.80)	1973-1971
Miami Beach, Florida	2.39 (+/1 0.43)	1931-1981
Vaca Key, Florida	2.78 (+/- 0.60)	1971-2006

Projections of future sea-level rise have recently become a topic of heated debate in scientific research. The IPCC's AR4 report summarised a range of sea-level rise projections under each of its standard scenarios, for which the combined range spans 0.18-0.59m by 2100 relative to 1980-1999 levels (see ranges for each scenario in Table 2.12-2). These estimates have since been challenged for being too conservative and a number of studies (e.g., Rahmstorf, 2007; Rignot and Kanargaratnam, 2006; Horton *et al.,* 2008) have provided evidence to suggest that their uncertainty range should include a much larger upper limit.

Total sea-level rises associated with atmospheric warming appear largely through the combined effects of two main mechanisms: (a) thermal expansion (the physical response of the water mass of the oceans to atmospheric warming) and (b) ice-sheet, ice-cap and glacier melt. Whilst the rate of thermal expansion of the oceans in response to a given rate of temperature increase is projected relatively consistently between GCMs, the rate of ice melt is much more difficult to predict due to our incomplete understanding of ice-sheet dynamics. The IPCC total sea-level rise projections comprise of 70-75% (Meehl *et al.*, 2007a) contribution from thermal expansion, with only a conservative estimate of the contribution from ice sheet melt (Rahmstorf, 2007).

Recent studies that observed acceleration in ice discharge (e.g., Rignot and Kanargaratnam, 2006) and observed rates of sea-level rise in response to global warming (Rahmstorf, 2007), suggest that ice sheets respond highly-non linearly to atmospheric warming. We might therefore expect continued acceleration of the large ice sheets resulting in considerably more rapid rates of sea-level rise. Rahmstorf (2007) is perhaps the most well cited example of such a study and suggests that future sea-level rise might be in the order of twice the maximum level that the IPCC indicates (up to 1.4m by 2100).

Table 2.12-2: Projected increases in sea-level rise from the IPCC AR4 (Meehl *et al.*, 2007a) contrasted with those of Rahmstorf (2007).

Scenario	**Global Mean Sea Level Rise by 2100 relative to 1980-1999.**	**Caribbean Mean Sea Level Rise by 2100 relative to 1980-1999 (+/ 0.05m relative to global mean)**
IPCC B1	0.18-0.38	0.13-0.43
IPCC A1B	0.21-0.48	0.16-0.53
IPCC A2	0.23-0.51	0.18- 0.56
Rahmstorf, 2007	Up to 1.4m	Up to 1.45m

2.13 *Storm Surge*

Changes in the frequency or magnitude of storm surges experienced at coastal locations in The Bahamas is likely to occur as a result of the combined effects of:

(a) Increased mean sea-level in the region, which raises the base sea-level over which a given storm surge height is superimposed, increasing the area affected by a storm surge of any magnitude.

(b) Changes in storm surge height, or frequency of occurrence, resulting from changes in the severity or frequency of storms
   1. Potential changes in storm frequency: some model simulations indicate a future reduction in storm frequency, either globally or at the regional level. If such decreases occur they may be offset by increases in flood frequency at a given land elevation.
   2. Potential increases in storm intensity: evidence suggests overall increases in the intensity of storms (lower pressure, higher near storm rainfall and wind speeds) which would cause increases in the storm surges associated with such events, and contribute further to increases in flood frequency at a given land elevation.

(c) Physical characteristics of the region (bathymetry and topography) which determine the sensitivity of the region to storm surge by influencing the height of the storm surge generated by a given storm.

In Sections 2.11 and 2.12 we discuss the potential changes in sea-level and hurricane intensity and frequency that might be experienced in the region under warming scenarios. The high degree of uncertainty in both of these contributing factors creates difficulties in estimating future changes in storm surge height or frequency. Typically, Caribbean Islands lack the high-resolution bathymetry and topography survey data that are required by storm surge models, which might be used to estimate the storm surge impacts based on projections of hurricane and storm characteristics under climate change scenarios.

Table 2.13-1: Approximate future return periods for storm surge static water levels that would flood current elevations above sea-level at Sangster International Airport. Data based on empirical examination of modelled return periods by Smith Warner International Ltd. for most likely static water elevations at Sangster (SWIL 1999). Wave run-up not included. Taken from Robinson and Khan (2008).

		Approximate Return periods (years) for flooding the current elevation.		
	Current Elevations	Present day Return Period SWIL 1999	2050 Projection (based on IPCC , 2007 SLR Projections)	2050 Projection (based on Rahmstorf, 2007 SLR Projections)
Sangster Airport	0.5	3.5 - 4	about 2	1.5
	1.0	7	about 5.5	5
	1.5	15	11.5	9
	2.0	100	56	33

2.14 *Conclusions and Recommendations*

Recent and future changes in climate on Eleuthera have been explored using a combination of observations and climate model projections. Whilst this information can provide us with some very useful indications of the changes to the characteristics of climate that we might expect under a warmer climate, we must interpret this information with due attention to its limitations.

- Limited spatial and temporal coverage restricts the deductions we can make regarding the changes that have already occurred. Those trends that might be inferred from a relatively short observational record may not be representative of a longer term trend, particularly where inter-annual or multi-year variability is high. Gridded datasets, from which we make our estimates of country-scale observed changes, are particularly sparse in their coverage over much of the Caribbean, such that those spatial averages draw on data from only a very small number of local stations combined with information from more remote stations.

- Whilst climate models have demonstrable skill in reproducing the large-scale characteristics of the global climate dynamics, there remain substantial deficiencies that arise from limitations in resolution imposed by available computing power, and deficiencies in scientific understanding of some processes. Uncertainty margins increase as we move from continental/regional scale to the local scale, as we have in these studies. The limitations of climate models have been discussed in the context of tropical cyclones/hurricanes, and sea-level rise in the earlier sections of this report. Other key deficiencies in climate models that will also have implications for this work include:
    - Difficulties in reproducing the characteristics of the El Niño – Southern Oscillation which exerts an influence of the inter-annual and multi-year variability in climate in the Caribbean, and on the occurrence of tropical cyclones and hurricanes.
    - Deficiencies in reliably simulating tropical precipitation, particularly the position of the Inter-tropical Convergence Zone (ITCZ) which drives the seasonal rainfalls in the tropics.
    - Limited spatial resolution restricts the representation of many of the smaller Caribbean Islands, even in the relatively high resolution Regional Climate Models.

  We use a combination of GCM and RCM projections in the investigations of climate change for a country and at a destination in order to make use of the information about uncertainty that we can gain from a multi-model ensemble together with the higher-resolution simulations that are only currently available from two sets of model simulations. Further information about model uncertainty at the local level might be drawn if additional regional model simulations based on a range of differing GCMs and RCMs were generated for the Caribbean region in the future.

3. VULNERABILITY PROFILE

3.1 *Introduction and the Affects of Climate Variability*

All sectors stated that they depend on warm tolerable weather, moderate wind and sunny skies to sustain their sector. Tourism is at stake in The Bahamas if the proportion of extreme weather events continues to increase. International and domestic travel figures decline in the hurricane season. The indirect costs of this are unknown. During inclement weather many hotels are forced to close as travel is cancelled and ports are closed. Some hotels compensate guests by offering refunds, but how sustainable is this?

During severe weather conditions there is an interruption to cruise ship services and ships are unable to dock. Port Authorities have to provide assistance to vessels in distress. In inclement conditions many vessels want to dock causing overcrowding and damage to other vessels. There is also a risk of vessels breaking loose and causing more damage.

The Bahamas has a high number of marinas which has its advantages. In Nassau when there is a threat of a hurricane, many boats are moved to another island and come back afterwards. This offers better protection for boaters.

National Parks are also closed as areas need to be made secure for vulnerable areas and animals. This causes a loss of revenue. Eco-tourism businesses also suffer during severe weather conditions as they rely on good weather (e.g., kayaking).

There is a spatial perception issue in that if a hurricane hits one Bahamian Island potential visitors perceive that the bad conditions have affected all of the Bahamian islands and may choose not to visit the country at all.

Global policy also has implications for tourism in the Caribbean (e.g., UK flight taxes).

3.2 *Water Quality and Availability*

The Bahamas relies on fresh groundwater for much of its water use needs, which is recharged by rainfall. The country's freshwater resources have been quantified and their spatial distribution is reasonably well defined (UNFCCC, 2004). The hydrogeology of The Bahamas, and its water resources, are directly linked as the country has no true rivers. The archipelago is made of up of over 2000 islands, cays and rocks, many of which have very little relief, resulting in minimal surface runoff and little opportunity to develop surface-water catchments (UNESCO-IHP, 2008). The groundwater resources occur as three-dimensional shallow lens-shaped bodies, which overlie brackish and saline waters. The size, shape and orientation of an island, its subsurface geology and the amount of rainfall control the shape, size and thickness of the freshwater bodies. It has been estimated that freshwater underlies only some 5% of the total land area of The Bahamas (UNFCCC, 2004). In excess of 90% of freshwater lenses are within five feet of the surface (UNESCO-IHP, 2008). Freshwater is also processed from seawater by reverse osmosis, through a desalinization plant (UNFCCC, 2001).

Rainfall in The Bahamas is extremely vulnerable to climate change due to the limited size of its islands, geology and topography (Mimura *et al.*, 2007). Lower rainfall can reduce the amount of groundwater that can be harvested, reduce river flow, and slow the rate of recharge of the freshwater lens, which can result in prolonged drought. Increases in sea-level may also shift freshwater resources close to or above the surface, resulting in increased evapo-transpiration, thus diminishing the resource (Mimura *et al.*, 2007). Over-extraction of freshwater resources can also result in salt water intrusion (UNFCCC, 2004). Fresh water resources are also threatened by human activity such as contamination from sewage, agricultural runoff and pollution from vehicles. The resources of the heavily populated islands of New Providence and Grand Bahamas are especially at risk by these activities (UNFCCC, 2001).

The scarcity of fresh water can limit social and economic development of the country. Local water shortages arise due to the spatial distribution of freshwater, the demands of local populations and from certain industries, in particular tourism (the largest demand for freshwater in The Bahamas). For instance, New Providence Island has often been unable to meet its demand for freshwater from its tourism industry and as a result, has shipped in fresh water from Andros Island (UNFCCC, 2001).

The North Andros Aquifer, located in North Andros Island, serves as the Caribbean case-study for the UNESCO-IHP's (International Hydrological Programme) *'Groundwater Resources Assessment under Pressures of Humanity and Climate Change (GRAPHIC)'* program. The North Andros Aquifer provides freshwater to the city of Nassau and the neighbouring areas. Its type of land formation is particularly vulnerable to sea-level rise, which could reduce the size of the island and push the freshwater lenses nearer the surface promoting its loss through greater evapotranspiration. Primary threats to groundwater on the island include storm surge, sea-level rise/ reduction in land-surface area, human demand and increase/ decrease precipitation (UNESCO-IHP, 2008).

The UNESCO-IHP program will run for five years and aims to assess the sustainability of groundwater resources in island settings under climatic and human stressors. Its objective is to identify and forecast the potential impacts of climate variability, climate change, land-use and human demand scenarios on groundwater resources in the island, and recommend groundwater management schemes. Outcomes include developing indicators to evaluate and assess the impacts of human activities and climate change on groundwater resources and partake in the development of guidelines for the establishment of appropriate groundwater monitoring systems and databases. The information will also be shared with other island nations with similar physiographic and hydrological settings (UNESCO-IHP, 2008).

3.3 *Energy Supply and Distribution (Regional, National & Destinational)*

It is widely acknowledged that the Caribbean accounts for only 0.2% of global emissions of carbon dioxide (CO_2), with a population of 40 million, corresponding to 0.6% of the world's population (Dulal *et al.,* 2009). However, in many countries, and in particular those that have developed their tourism systems, per capita emissions are already exceeding levels that can be considered sustainable (Table 3.3-1). Countries like Aruba (21 t CO_2 per capita/year), Antigua and Barbuda (5 t CO_2 per capita/year), or The Bahamas (6 t CO_2 per capita/year) all have per capita emission levels that are close to or even exceed those in developed countries, and many exceed the global average of about 4.3 t CO_2 per capita per year (UNSD, 2009). If the Caribbean's contribution to global emissions of carbon dioxide is currently still comparably low on a regional basis, i.e., 0.2% of global emissions, this is largely due to populous islands including Cuba and Haiti and their comparably low per capita emission levels. If all countries have emission levels such as The Bahamas, the region would considerably exceed its emission share to population ratio, i.e., be an above average contributor to climate change. This also means that countries like Aruba might face emission reduction demands as Annex I countries in the near future. Importantly, with the exception of Cuba, Martinique (negative) and The Bahamas (modestly positive), all countries in Table 3.3-1 show strong growth in emissions, i.e., in the order of 17-145% since 1990. The islands are thus increasingly at odds with global climate policy.

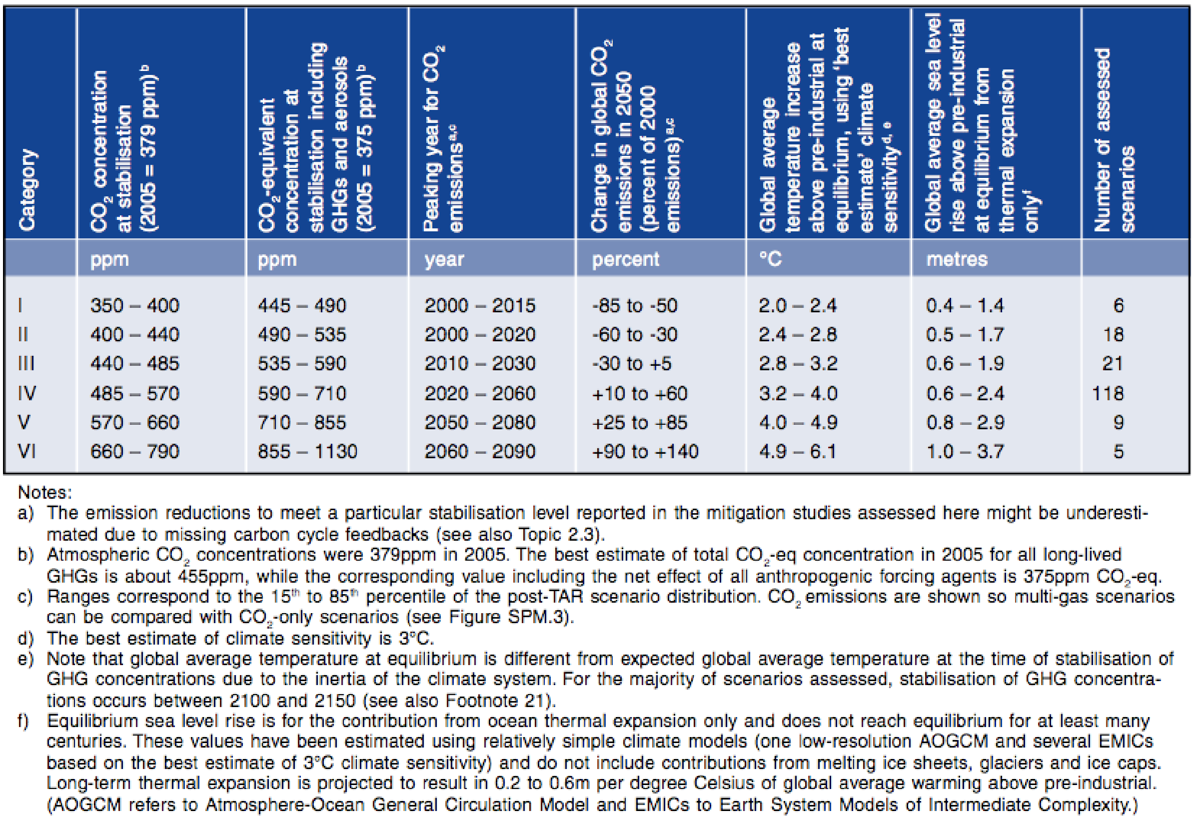
Table 3.3-1: Carbon dioxide emissions from Caribbean countries

	Year	CO_2 emissions	Change since 1990	CO_2 emissions per capita/year
		mio. tonnes	%	Tonne / person
Antigua and Barbuda	2004	0.41	37.8	5.06
Aruba	2004	2.16	17.1	21.32
Bahamas	2004	2.01	3.0	6.29
Barbados	2004	1.27	17.7	4.36
Cayman Islands	2004	0.31	25.0	6.97
Cuba	2004	25.82	-19.5	2.30
Dominica	2004	0.11	81.2	1.56
Dominican Republic	2004	19.64	105.2	2.11
Grenada	2004	0.22	78.8	2.07
Guadeloupe	2004	1.73	35.1	3.99
Haiti	2004	1.76	76.8	0.19
Jamaica	2004	10.59	33.0	3.97
Martinique	2004	1.29	-37.4	3.27
Saint Kitts and Nevis	2004	0.12	88.9	2.57
Saint Lucia	2004	0.37	127.3	2.30
St. Vincent and the Grenadines	2004	0.20	145.5	1.67
Trinidad and Tobago	2004	32.56	92.4	24.68
US Virgin Islands	2003	13.55	60.1	121.30

Source: UNSD, 2009

These insights are of importance in light of the post-Kyoto negotiations, which the IPCC recommends should aim at cutting global carbon dioxide emissions by at least 50% by 2050 (IPCC, 2007c). This would be a minimum requirement to avoid global average temperature increases beyond 2°C by 2100 (see Table 3.3-2), or what is generally seen as the maximum level of global warming "avoiding dangerous interference with the climate system" (e.g., Meinshausen *et al.*, 2008).

Table 3.3-2: Characteristics stabilisation scenarios and resulting long-term equilibrium global average temperature



Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d, e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:

a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).

b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.

c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).

d) The best estimate of climate sensitivity is 3°C.

e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).

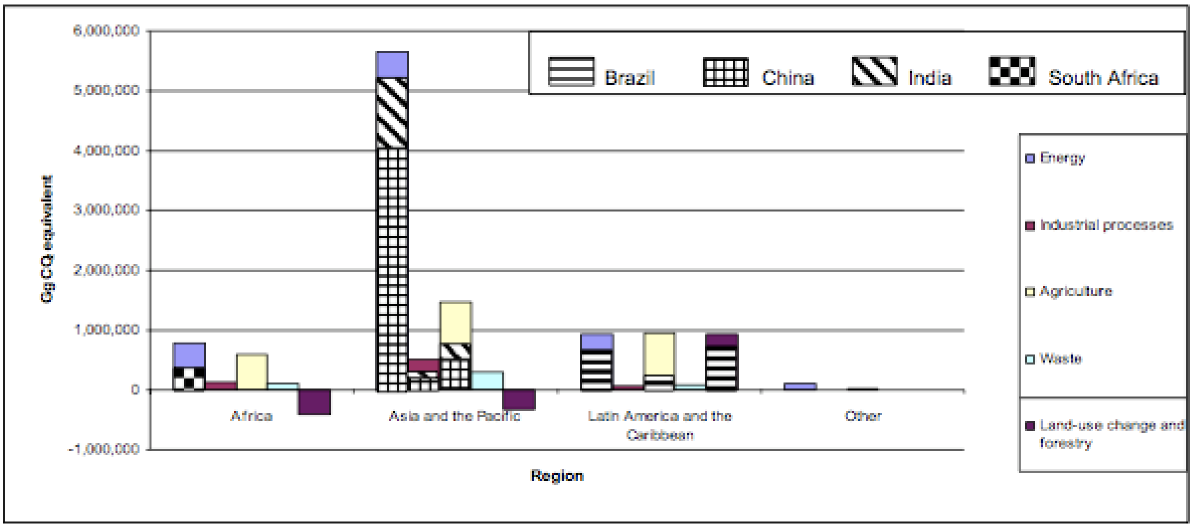
f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

Source: IPCC 2007c

In this context, it is important to understand the processes that generate emissions in the Caribbean. Figure 3.3-3 (UNFCCC, 2005) shows emissions by the non-Annex I region and sector, including energy, industrial processes, agriculture, waste and land use change and forestry. As the figure reveals, emissions in Latin America and the Caribbean arise largely from energy use (fossil fuels), agriculture and land use change. Much of the total is a result of emissions in Brazil, while the Caribbean accounts for only a small share of the overall total. Nevertheless, it seems clear that most of the emissions from the Caribbean are a result of energy use, and in particular fuels (e.g., Dept. of Statistics of the Bahamas, 2009; Central Bureau of Statistics Aruba, 2009). Even though the statistical database for this is not always given, a considerable share of fuel imports can again be linked to tourism, particularly in those islands highly dependent on tourism (Gössling *et al.,* 2008). Table 3.3-3 shows that in countries like Cuba, each tourist arrival entails emissions corresponding to roughly one third of the currently sustainable per capita emissions budget (cf. Gössling *et al.,* 2008). Jamaica has a considerably more favourable per tourist carbon footprint (0.6 t CO_2 per arrival) due to its greater proximity to its main market.

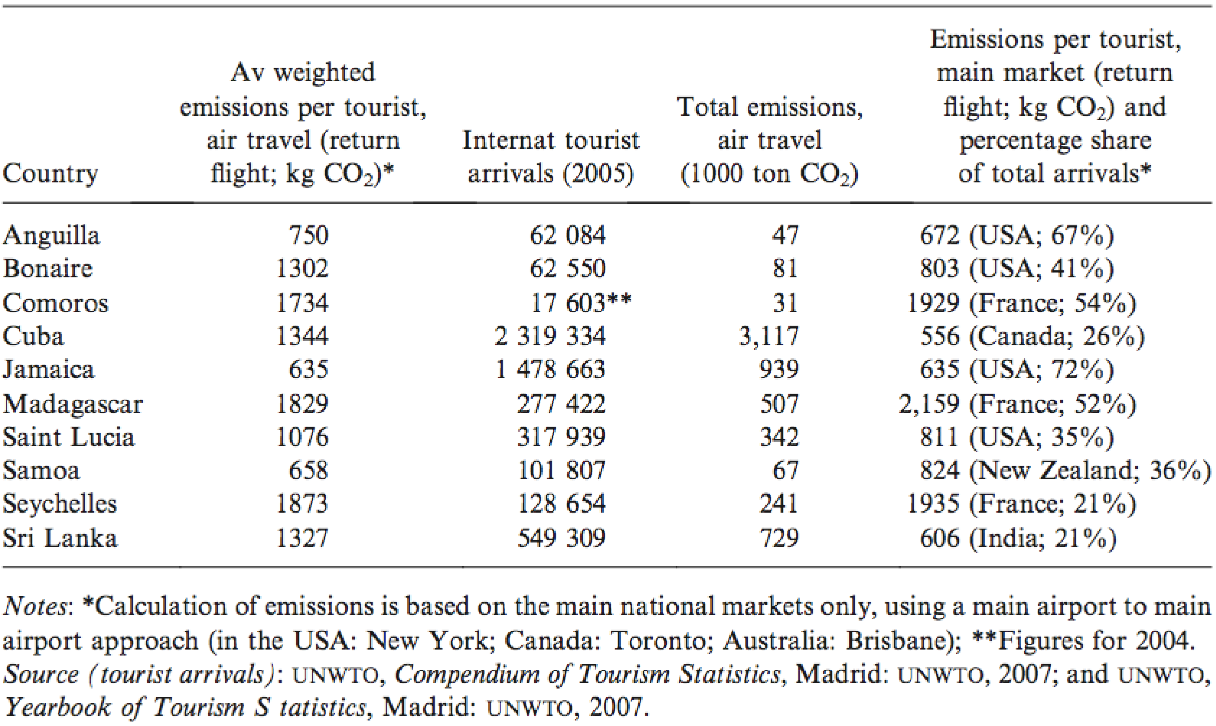
Figure 3.3-3: Aggregate GHG emissions and removals by sector by region for the year 1994 of the closest year reported.

Figure 3. Aggregate GHG emissions and removals by sector by region (Gg CO_2 equivalent) for the year 1994 or the closest year reported



Source: UNFCCC (2005)

Table 3.3-3: Energy characteristics of tourism in case study islands (2005)



Country	Av weighted emissions per tourist, air travel (return flight; kg CO_2)*	Internat tourist arrivals (2005)	Total emissions, air travel (1000 ton CO_2)	Emissions per tourist, main market (return flight; kg CO_2) and percentage share of total arrivals*
Anguilla	750	62 084	47	672 (USA; 67%)
Bonaire	1302	62 550	81	803 (USA; 41%)
Comoros	1734	17 603**	31	1929 (France; 54%)
Cuba	1344	2 319 334	3,117	556 (Canada; 26%)
Jamaica	635	1 478 663	939	635 (USA; 72%)
Madagascar	1829	277 422	507	2,159 (France; 52%)
Saint Lucia	1076	317 939	342	811 (USA; 35%)
Samoa	658	101 807	67	824 (New Zealand; 36%)
Seychelles	1873	128 654	241	1935 (France; 21%)
Sri Lanka	1327	549 309	729	606 (India; 21%)

Notes: *Calculation of emissions is based on the main national markets only, using a main airport to main airport approach (in the USA: New York; Canada: Toronto; Australia: Brisbane); **Figures for 2004. *Source (tourist arrivals)*: UNWTO, *Compendium of Tourism Statistics*, Madrid: UNWTO, 2007; and UNWTO, *Yearbook of Tourism S tatistics*, Madrid: UNWTO, 2007.

Source: Gössling *et al.* (2008)

Workshop results
Seasonal variations in energy demand, climate influences on shipping channels and the supply of fossil fuels affect the energy sector. The country relies greatly on fossil fuel, of which only a three month reserve is held. Nothing is currently being done to move towards better practices.

When the temperature increases demand for electricity goes up. Humidity affects electrical activity and the ability to provide power to the city. In extreme weather it is not safe to provide electricity because of power transmission, fragile infrastructures and the specific geographical features of The Bahamas. The situation is even more complicated on the out islands where infrastructures are poor, fragile and old. Underground cabling seems to be one solution. For example, in the last storm, the area with underground cabling suffered no loss of power. However underground cabling is five times more costly than overhead cabling.

It was suggested that a sustainable tourism project is developed, such as energy efficient light-bulbs on Harbour Island. It was also felt that energy efficiency is better addressed by the tourism industry than other sectors; however there is a high cost of retro-fitting. It may be better to put this in place in new developments.

3.4 *Agriculture, Fisheries and Food Security*

The agriculture and fisheries sectors in The Bahamas are small and account for 3 to 5 % of GDP, with agriculture contributing to 1-2% of GDP and fisheries contributing to 2-3% of GDP. The agriculture sector produces substantial quantities of broilers[1] and eggs, though a large proportion (approximately 85%) of the food consumed in the country is imported. Most attempts at commercial agriculture have been unsuccessful, due to exhaustion of the country’s thin, coarse-textured and fragile soils (UNFCCC, 2001).

Communities on the less developed islands depend on subsistence agriculture (crop production and animal husbandry) for a part of their livelihood. Many of their short-term crops (corn, pigeon peas, sweet potatoes and vegetables) are seasonal and any significant shifts in climate could have negative effects on production and food supply (UNFCCC, 2001). Projected impacts to agriculture and food security, by climate change, include extended periods of drought and loss of soil fertility and degradation due to increased precipitation (Mimura *et al.*, 2007). Increased atmospheric CO_2 concentrations could positively enhance the growth and yield of certain crops, yet could also favour certain weed species over crop species (UNFCCC, 2001). Flooding by storm surges and sea-level rise could also result in the loss of agricultural land due to saltwater intrusion and salinization (UNFCCC, 2001). Delivery of imported food could also be affected by an increase in extreme weather events (i.e., hurricanes) [interview results].

The shallow water banks of The Bahamas are rich in fish. Climate change could damage coral reefs and coastal wetlands, which could impair their "nursery" role for commercial fish species. Changes in ocean temperatures could also impact the migration of fish and other marine life forms (UNFCCC, 2001). Further information, from species biology to the behaviour of whole ecosystems, needs to be collected at the local, national and regional levels to more fully assess the impacts of climate change on fisheries (UNFCCC, 2004). Interview participants stated that storms and hurricanes are responsible for destroying aquaculture infrastructures and for wiping out certain marine species.

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[1] Chickens bred for frying.

3.5 *Human Health*

The Caribbean lies in a tropical zone with weather conducive to the transmission of vector-borne, as well as food and water borne diseases. The rates of many of these diseases are increasing in small island states due to poor public health practices, inadequate infrastructure, poor waste management practices, increasing global travel and changing climatic conditions (WHO, 2003). Climate change will lead to an increase in health related illness and disease in the Caribbean, through direct and indirect effects.

Direct effects of climate change on human health include deaths from extreme weather events (tropical cyclones, storm surges, hurricanes, flooding and heat waves). It is anticipated that an increased frequency or severity of heat waves in the Caribbean would cause an increase in human mortality and illness especially among poor communities without access to cooling aids like air conditioners or refrigeration. Increased frequency of other extreme weather events would also result in increased deaths, physical injury, increased disease transmission, decreases in agricultural productivity and increases in psychological disorders (Dulal *et al.*, 2009; Mimura *et al.*, 2007).

Indirect effects of climate change on human health include vector[2]-borne diseases (dengue fever, malaria and yellow fever and leptospirosis). As the replication rate of many infectious agents, vector organisms and non-human reservoir species are sensitive to climatic conditions; climate change is expected to increase the incidence of certain vector-borne diseases. For instance, temperature plays a very important role in speeding up the maturation of the malarial parasites inside the mosquitoes. An increase of 5 °C, for example from 20 °C (68 °F) to 25 °C (77 °F) reduces the Plasmodium falciparum (malarial protozoa) maturity period by half the time (from 26 days to 13 days) (Dulal *et al.*, 2009).

With a rise in the occurrence of extreme events, availability of freshwater may also be constrained and contaminated. This could lead to communities experiencing food and water-borne and respiratory diseases (i.e., cholera, salmonellosis, and asthma[3]), especially in remote or rural communities that have minimal public health care infrastructures (Dulal *et al.*, 2009; Mimura *et al.*, 2007). Malnutrition resulting from disturbances in food production or distribution could also occur.

Another potentially important category of health impacts would result from the deterioration in social and economic circumstances that might arise from adverse impacts of climate change on patterns of employment, wealth distribution, population mobility, and limited resettlement prospects (Dulal *et al.*, 2009). Some people could suffer post-traumatic stress related to climate disasters (interview results). Access to health care could also be limited if infrastructure is damaged due to adverse weather conditions.

3.6 *Marine and Terrestrial Biodiversity, and Landscape Aesthetics*

The Bahamas has a rich marine and terrestrial biological diversity, though a large portion of the country remains unexplored, as only approximately 5% of all species present in the country have been identified to date (UNFCCC, 2004). The country's isolation and extensive shelf with productive coral reefs and other habitats, plus a large area of coastal wetlands, especially mangrove forests, contribute to its abundance and diversity of migratory fish and mammal species, awarding The Bahamas the greatest marine biodiversity in the Caribbean (UNFCCC, 2001; UNFCCC, 2004).

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[2] Insect and rodent.

[3] Other water-borne diseases include schistosomiasis, cryptosporidium; other food-borne diseases include diarrhoeal diseases, food poisoning and typhoid; other respiratory diseases include bronchitis and respiratory allergies and infections (WHO, 2003).

The Bahamas' coastal, marine and deep waters comprise more than 96% of the country's total area. Climate change impacts to marine biodiversity include sea-level rise and changes in ocean temperatures impacting upon the migration of fish and other marine life forms. For instance, a 0.5 m rise in sea-level is projected to cause a decrease in turtle nesting habitat by up to 35% (Fish *et al.,* 2005). Damage to coral reefs and coastal wetlands could also impair the "nursery" role of these habitats for commercial fish species.

Coral reefs are expected to be additionally stressed through higher sea surface temperatures, which can lead to coral bleaching, which has already been noted across The Bahamas. The coral reefs of the country are the third most extensive coral reef system in the world, support a variety of commercially important marine resources and serve as physical barriers to storm surge and ocean waves (UNFCCC, 2001). Coral bleaching could become more frequent in the next 30 to 50 years or sooner without an increase in thermal tolerance of 0.2 to 1.0°C (Sheppard, 2003; Donner *et al.*, 2005). Bleaching further weakens reef systems and damages their ability to withstand the impact of other extreme events (i.e., hurricanes and storm surges) which reduces their ability to maintain protection against beach erosion. Interview respondents stated that damage to corals from bleaching in The Bahamas is less severe than on other Caribbean islands (i.e., Jamaica). Reefs are also threatened from over-exploitation, pollution from run-off and sewage, and non-sustainable practices associated with diving and tourist related industries (UNFCCC, 2001).

Elevated sea level temperature could also lead to increased occurrence of algal blooms, sometimes called "red tides". The causative bio-toxins in the algal blooms can cause serious food poisoning, as they accumulate in the food chain by persons consuming scale fish and shellfish containing accumulated bio-toxins. Ciguatera is a key bio-toxin in the Caribbean. Further information needs to be collected on the red tides and the occurrence of ciguatera and other toxins in The Bahamas (UNFCCC, 2001).

Terrestrial biodiversity in the area of wetlands and saline soils will also be impacted by increases in the incidence of flooding. Forests in The Bahamas consist of pine, coppice and mangrove forests (wetlands). The pine forests are considered the most productive and commercially viable and are a protected species. Forest biodiversity could be affected by extreme events such as hurricanes, as adaptation responses on small islands are expected to be slow, and impacts of storms may be cumulative (Mimura *et al.*, 2007). A slow, gradual, rise in sea-level will also increase the area of wetlands in The Bahamas, which occur predominantly on the lee shores of most the islands. This, in turn, is expected to lead to the gradual evolution of pine forests and coppice forest to perennial wetlands, with consequent changes in the fauna and flora. At the extreme projection of a sea-level rise of 5 ft (1.5 m), above present sea-level, some 80 % of the land mass of The Bahamas will be reclaimed by the sea for most, if not all, the year (UNFCCC, 2001).

Less than 5% of the total area of The Bahamas accounts for total land mass and approximately 80% of the country is within 5 to 6 ft (1.5 to 1.8 m) of mean sea level (UNFCCC, 2004). Historically large expanses of land on all of the major inhabited islands were subsistence farmed. Once land was farmed for a few years it became exhausted and farmers cleared new acreage for planting. Some of these ventures were successful but eventually succumbed because of soil depletion. The soils of The Bahamas are now very thin, calcareous, fragile, have low fertility and are droughty. Land currently sees increasing development from tourism and other commercial sectors (UNFCCC, 2001). Inefficient land development can lead to increased soil erosion, loss of agricultural productivity, deforestation, and deteriorating water quality (freshwater and marine). Land, its settlements and infrastructure are projected to be further impacted by climate change, through rising sea levels and extreme events (such as cyclones) leading to coastal erosion.

3.7 *Infrastructure and Settlements*

In the Caribbean more than half of the population live within 1.5 km of the shoreline (Mimura *et al.*, 2007). The Bahamas is no exception to this, as the majority of its infrastructure and settlements are located at or near the coast, including government, health, commercial and transportation facilities. A global scale analysis of the vulnerability of developing nations to sea-level rise by the World Bank in 2007 (Dasgupta *et al.*, 2007) found that several Caribbean nations were among the most impacted nations from climate change in terms of land area lost, percentage of population and GDP affected. The Bahamas was ranked in the top 10 of impacts for developing nations for each of these important indicators. Climate change poses several risks to infrastructure and settlements in the country, including changes in extreme precipitation events that cause localized or watershed level flooding; increases in the frequency or intensity of storm events causing damage from wind, rain or storm surges, and in the longer term sea-level rise and attendant damage from inundation or coastal erosion. This could lead to key facilities being at serious risk from inundation, flooding and physical damage associated with coastal land loss (i.e., roads, hospitals, hotels and farm land) (Mimura *et al.*, 2007).

Despite this potential vulnerability, knowledge of coastal response to climate change and sea-level rise remains underdeveloped in The Bahamas. As indicated, most Caribbean Islands lack the high-resolution topography data required to assess potential storm surge impacts based on projections of hurricane and storm characteristics under climate change scenarios. As this was considered a critical vulnerability for the study area, addressing this information gap was a priority for the research team.

As outlined in section 2.10, projected changes in rainfall extremes (1- and 5-day rainfall totals) are mixed, with a trend toward slight decreases MAM and slight increases in SON and DJF. However, increases in rainfall intensity during hurricane and tropical storm events are widely anticipated (section 2.11). The high variability of rainfall in the study area currently, particularly during hurricane and tropical storm events, and the lack of extensive upstream water accumulations in the local watersheds, suggest that storm water management systems constructed to accommodate current extreme events should not require major reengineering to accommodate projected changes in extreme rainfall. However, where storm water management systems are currently overwhelmed by extreme rainfall and localized flooding occurs or where new infrastructure investment is planned; engineering should be designed to accommodate the possibility that future extremes may exceed those in the limited historical climate record.

The implications of the higher range of peak wind speeds increased projected for tropical cyclones in the region (+3 to +20% - section 2.11) for infrastructure damage is significant. Such an increase would necessitate a review of design wind speeds in building codes in the study area and likely require future investment to protect strategic infrastructure as part of mainstreaming climate change adaptation. As the relationship between wind speed, damage and insurance losses are non-linear (Owens and Holland, 2009; Nordhaus, 2006), there are also implications for increased insurance premiums associated with climate change induced risk. A report by the Association of British Insurers (2007) estimate that by the mid to late-21st century, premiums in the US Gulf Coast and Caribbean region would need to increase 20 to 80% in response to altered risk profile and some high risk areas would become uninsurable.

The Caribsave partnership coordinated a field research team with members from the University of Waterloo (Canada), Oxford University (UK) and the Bahamas Meteorological Service to complete detailed coastal profile surveying. The field team conducted 15 survey transects (perpendicular to the shoreline) at all locations on Eleuthera Island and Harbour Island where tourism infrastructure was present and in two locations where future development was planned. The sites were surveyed using Trimble Geo-XT(R) satellite-based augmentation system (SBAS) differential GPS units with sub-metre accuracy in both horizontal and vertical planes. The team utilized two rover packs to increase efficiency allowing for two teams to make transects simultaneously (Figure 3.7-1). Vertical measurements were adjusted according to the height of the receiver relative to the distance to the ground. Distance between points along transects were measured using a Lecia Disto laser distancing meter. Transects were spaced at approximately 30-50m intervals depending on the length of the beach of interest and variability in topography along the beach. The water's edge was fixed to a datum point of 0 for the field measurements, but later adjusted according to tide charts. Generally, satellite connections were very good, receiving up to 10 satellites, resulting in sub-metre accuracy. The mean vertical accuracy for all points was approximately 0.6 m while the horizontal accuracy had a mean average of 0.5 m accuracy. Each transect point measurement was averaged over 30 readings taken at 1 second intervals. At each point, the nature of the ground cover (e.g., sand, vegetation, concrete) was logged to aid in the post-processing analysis. Ground control points were taken to anchor the GPS positions to locations that are identifiable from aerial photographs to improve horizontal accuracy. These were taken where suitable landmarks at each transect location and throughout the island. GCP points were measured over 60 readings at 1 second intervals. At each GCP, the physical characteristics of the site were logged to enable the point to be identified from areal images. Photographs were taken from north, south, east and west perspectives to aid this process. The GCP points were also collected as a means of geo-referencing digital satellite imagery for the study sites.

Figure 3.7-1 High Resolution Coastal Profile Surveying with GPS

Following the field collection, all of the GPS points were downloaded on to a Windows PC, and converted into several GIS formats. Most notably, the GPS points were converted into ESRI Shapefile format to be used with ESRI ArcGIS suite. Aerial Imagery was obtained from Google Earth, and was geo-referenced using the 22 GCP collected throughout Eleuthera and Harbour Island. The data was then inspected of all errors and incorporated with other GIS data collected while in the field. The first step in the post processing was determining the position of the absolute mean sea level by comparing the first GPS point (waters edge) to tide tables to determine the high tide mark. The second step was to produce three dimensional topographic models of each of the 15 study sites. First a raster topographic surface was created, using the GPS elevation points as base height information. Similarly, a Triangular Irregular Network (TIN) model was created to represent the beach profiles in three dimensions. Contour lines were delineated from both the TIN and raster topographic surface model. For the purpose of this study, contour lines were represented for ever metre of elevation change above sea level. Using the topographic elevation data, flood lines were delineated in one metre intervals. In an effort to share the data to a wider audience, all GIS data will be compatible with several software applications, including Google Earth.

Figure 3.7-2 SLR Study Areas on Eleuthera Island

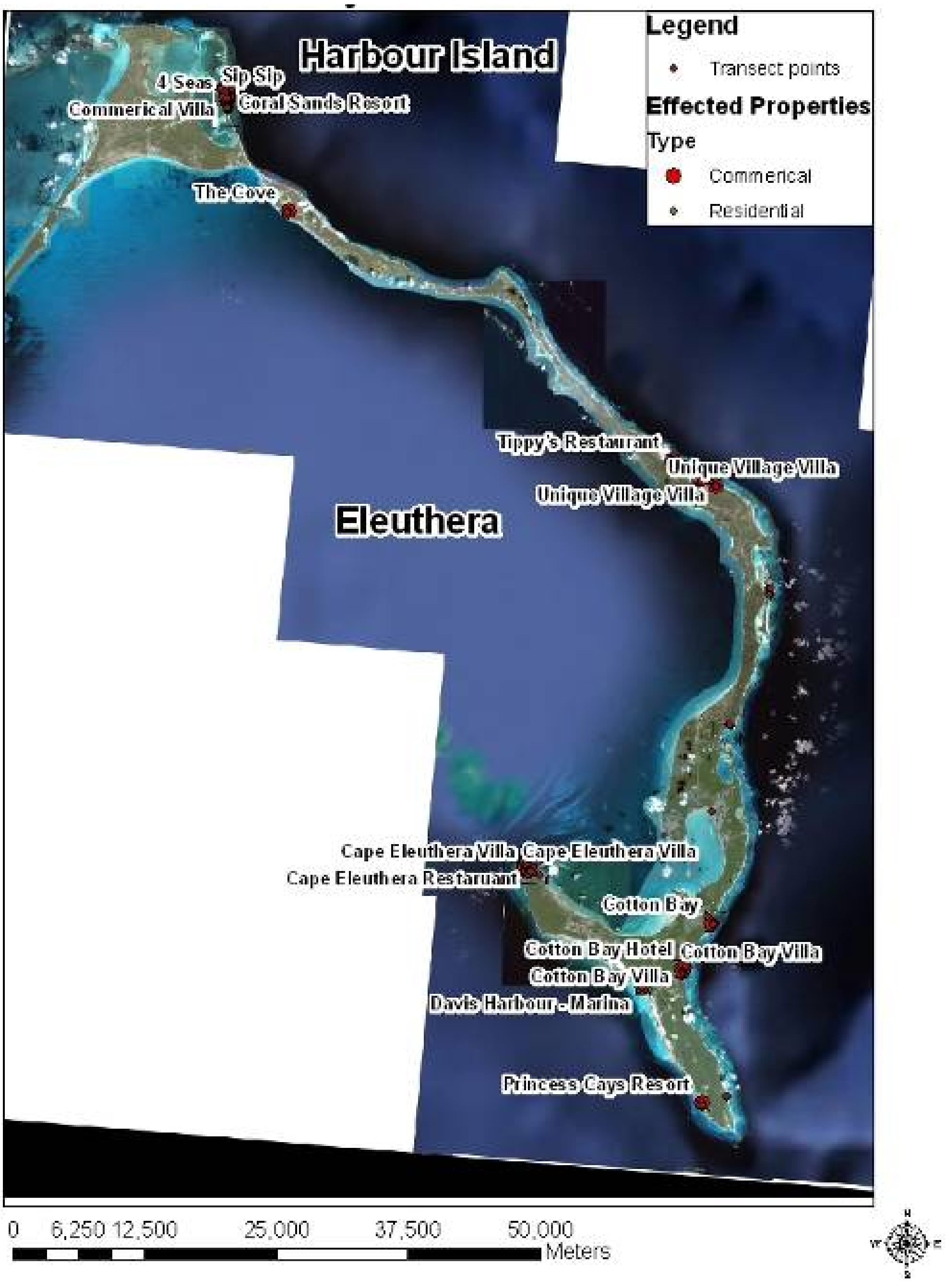
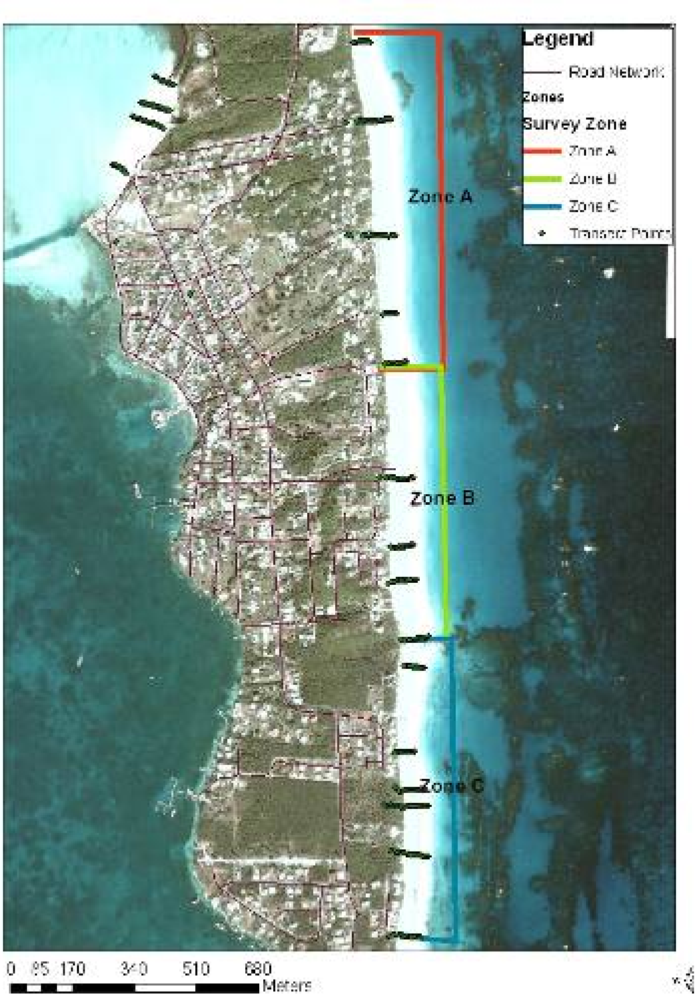


Figure 3.7-3: GPS Surveying Transects on Harbour Island



Based on the sea-level rise scenarios for the Caribbean and the storm surge projections for The Bahamas (see sections 2.12 and 2.13) and consistent with other assessments of the potential impacts of sea-level rise (e.g., Dasgupta *et al.,* 2007 for the World Bank), four sea-level rise scenarios were mapped (0.5m, 1.0m, 2.0m, and 3.0m) to assess the potential vulnerability of major tourism resources (specifically critical beach areas) and major tourism infrastructure (resort complexes, other accommodations, road networks) to inundation by the sea and exposure to storm surge flooding damage. The land areas on Harbour Island that are at risk to inundation or flooding damage from storm surge are identified in Figures 3.7-4 (zone A and B) and 3.7-5 (zone C) by the coloured lines for the 0.5m, 1.0m, 2.0m, and 3.0m contours. In addition to inundation and storm surge related flooding, sea-level rise will also cause increased erosion of newly exposed coastal areas. The prediction of how sea-level rise will reshape coastlines is not trivial and is influence by a range of coastal morphological factors (coastal geology, bathymetry, waves, tidal currents, human interventions). The most widely used method of quantifying the response of sandy coastlines to rising sea levels is the Bruun Rule, which is appropriate for assessing shoreline retreat caused by the reestablishment of equilibrium beach profile inland by the erosion of beach material from the higher part of the beach and deposition it in the lower beach zone (Zhang *et al.,* 2004). A simplified approximation of the Bruun Rule (shore recession = sea-level rise X 100) that has been used in other studies on the implications of sea-level rise for coastal erosion was adopted for this analysis, and the resulting erosion related to a 1m sea-level rise is mapped as a red dashed line in figures 3.7-4 and 3.7-5.

Analysis of the tourism resources and infrastructure at risk under each sea-level rise scenario and erosion risk determined from the application of the Bruun Rule to a 1m sea-level rise was conducted with a GIS. For example, figure 3.7-6 illustrates the calculation technique for beach and land areas inundated by a 3m sea-level rise or storm surge.

Even under a 0.5m sea-level rise, 69% of the highly valued beach resource on Eleuthera and Harbour Islands would be inundated (Table 3.7-1). The response of tourists to such a diminished beach area remains an important question for future research; however local tourism operators perceive these beach areas along with climate to be the island's main tourism products. Table 3.7-2 further identifies what tourism infrastructure would be at risk to inundation of 0.5 and 1.0m sea-level rise and to storm surges of 2m and 3m. As Figures 3.7-4 and 3.7-5 clearly illustrate, the longer term erosion response of the shoreline to a 1m sea-level rise (dashed red lines) would have significant implications for the shoreline and the loss of a total of 7 high value commercial tourism properties and 71 private residents along the western shore of Harbour Island.

The high resolution imagery provided by this technique is essential to assess the risk of infrastructure and settlements to future sea-level rise, but its ability to identify individual properties also makes it a very powerful risk communication tool. Having this information available for community level dialogue on potential adaptation strategies will be highly valuable.

Figure 3.7-4 Sea Level Rise Vulnerability on Harbour Island – Zone A and B

Figure 3.7-5 Sea Level Rise Vulnerability on Harbour Island – Zone C

Figure 3.7-6 GIS Analysis of Vulnerability to a 3m Sea Level Rise /Surge on Harbour Island – Zone B

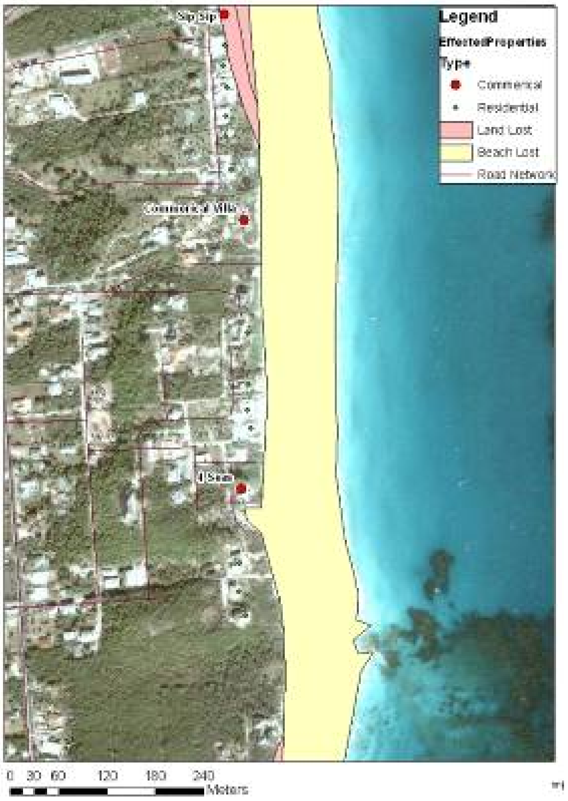


Table 3.7-1 Eleuthera and Harbour Island Beach Resources at Risk to Sea Level Rise

SLR Scenario	Beach Area Lost m^2	Percentage of Beach Area Lost
0.5 Metre	144894	69.34%
1.0 Metre	155278	74.31%
2.0 Metre	179715	86.01%
3.0 Metre	208959	100.00%

Table 3.7-2 Eleuthera and Harbour Island Commercial Property at Risk to Sea Level Rise

Name	SLR Scenario (Metres)	Impacts
Princess Cays Resort	0.5, 2	100 % Beach gone by 0.5m, buildings 2m
Davis Harbour	3	100 % Beach Loss
Cotton Bay Villa	2	100 % Beach loss
Cotton Bay Villa	2	100 % Beach loss
Paradise Sands (Captain Jacks)	3	100 % Beach loss
Cape Eleuthera Villa	2, 3	100% Beach loss by 2m, building affected 3m
Cape Eleuthera Restaurant	2, 3	100% Beach loss by 2m, building affected 3m
Cape Eleuthera Villa	0	100% Beach loss by 2m, building affected 3m
Tippy's Restaurant	3	100% Beach loss by 2m, building affected 3m
The Cove	3	100% Beach loss by 3 m
Cotton Bay Hotel	2	100% Beach lost and building affected
Commerical Villa	3	75% Beach loss by 3m
Sip Sip	3	100% Beach lost, 75% of structures affected
4 Seas Resort	3	85% Beach loss
Unique Village Villa	3	95 % Beach loss
Unique Village Restaurant	3	95 % Beach loss
Unique Village Villa	3	95 % Beach loss
Cotton Bay Main Building	3	95 % Beach loss
Coral Sands Resort - Hotel	3	100% Beach lost, lawn portion of accommodations
Coral Sands Resort - Restaurant and Bar	3	100% Beach lost, restaurant building and blue bar
Dunmore Beach Club	3	100% Beach lost, some of building underwater

3.8 *Comprehensive (Natural) Disaster Management*

As detailed earlier, much of the biological diversity, infrastructure, industries and communities of The Bahamas will be increasingly prone to natural disasters under climate change, in particular sea-level rise and extreme events such as hurricanes, floods and drought.

To address disaster management in the Caribbean tourism sector, the Caribbean Disaster Emergency Response Agency (CDERA) with the support of the Inter-American Development Bank (IDB) and in collaboration with the Caribbean Tourism Organization (CTO), CARICOM Regional Organization for Standards and Quality (CROSQ), and the University of the West Indies (UWI) will be implementing a Regional Disaster Risk Management (DRM) Project for Sustainable Tourism over the period of January 2007 to June 2010. The project aims to reduce the Caribbean's tourism sector vulnerability to natural hazards through the development of a '*Regional DRM Framework for Tourism*'. Under the Framework, a '*Regional DRM Strategy and Plan of Action'* will be developed, with a fundamental component being the development of standardized methodologies for hazard mapping, vulnerability assessment and economic valuation for risk assessment for the tourism sector (CDERA, 2007; CDERA, 2009).

Post Disaster Management: BEST commission checks of the environmental state after events: it checks mangroves, marinas (to avoid spilling) and then launch reforestation projects or help rebuild. **BREEF** takes action with two units. The Control Unit deals with flooding, mosquitoes, rodent moves, sewage monitoring, potable water testing, pest, seawalls consolidation. The Investigators Unit monitors rain, flood, moisture, mould, air quality. **Ministry of Works** checks assess and give estimate to repair people's residence and public buildings and place people in other venues.

Policies have been put into place to protect against severe weather conditions. Building Codes stipulate that buildings should be able to withstand winds of a Category 5 Hurricane. Buildings on the coast should not be built over the high water mark or 75 feet away from the water. Although property buyers still want to buy within a close proximity to the coastline.

Agencies have started to assess the implications of climate change with the use of Environmental Impact Assessment (EIA). This is now a requirement for any development in The Bahamas. It looks at the biological and physical environment as well as providing any future projections of climatic impacts such as erosion.
Agencies have also reviewed policies to prevent the loss of resources due to weather conditions such as no build zones.

3.9 *Identification of the Most Vulnerable*

Impacts of climate change will be differently distributed among different regions/destinations, generations, age classes, income groups, occupations and genders (IPCC, 2007a). In light of the estimated current annual rate of climate change related deaths of 300,000, which is anticipated to increase to 500,000 by 2020 (Global Humanitarian Forum, 2009), it is of great importance to identify the most vulnerable groups in society in order to develop adaptation strategies tailored to them. As outlined in the previous sections, adaptation will be particularly relevant in high-risk areas, including coastlines. Moreover, the most vulnerable groups are generally those with limited financial resources, and those who are also dependent on agriculture or forestry (IPCC, 2007a; Ketwaru-Nurmohamed, 2008). In the context of the Caribbean, those dependent on tourism might be added to this list, particularly when employed in low-paid service industry positions (cf. Massiah, 2006). Within these groups, yet another sub-division might be made between men and women, for reasons to be discussed in the following section (Gender). Dunn

(2008) also distinguishes groups that are more vulnerable for various specific reasons, including restricted access to early warning systems, because of gender roles working to a disadvantage in a disaster situations, limited social participation or social disadvantages such as lack of education, poor housing or inadequate food supplies, or the gender division of labour. Conclusions regarding vulnerability will be drawn based on these considerations.

3.9.1 Gender

It is now increasingly recognized that vulnerabilities are closely interlinked with gender, and that women in many areas are particularly vulnerable (for a discussion of exceptions to this general rule see e.g., Dunn, 2008). One example is the 1991 cyclone disaster in Bangladesh, where 90% of casualties were reportedly women (Aguilar, 2004). With regard to the Caribbean, a number of general insights regarding vulnerabilities can be derived from Massiah's (2006) review of women's rights. Massiah (2006:60) concludes that, formally, much progress has been made with regard to women's rights, and that the Caribbean was the first region to ratify the Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW Convention): "it can be said that the region has embraced the principle of gender equality as a fundamental tenet of its development agenda". However, differences between countries in the Caribbean remain large, as reflected in the countries' respective ranking in Gender Development Indices and the so-called Gender Empowerment Measure. Massiah (2006: 60) thus suggests that:

> *The reality is that the segregated nature of the labour market continues, there continue to be unacceptable levels of violence, particularly domestic violence, discrimination which once may have been institutionalised has gone underground bust still exists, women's right to control their own sexual and reproductive rights continues to be challenged, few women are to be found in key leadership positions and women continue to be disproportionately represented among the poor.*

With regard to climate change and adaptation, Massiah (2006) does not make an explicit link to the topic, but lists several issues of importance. First, a considerable share of women in the Caribbean have income levels beyond the poverty line, or are unemployed and engaged in the informal sector. The informal sector is generally characterized by a greater share of women, whose work yields lower and less stable earnings than the work of men. Garment, electronic factories, offshore financial sectors and tourism are mentioned by Massiah (2006) as sectors particularly vulnerable to change, and as exemplified by the consequences of globalization as experienced in the early 1990s. It might be argued, however, that shocks to the system could also result from extreme weather situations deterring, for instance, tourists.

More specifically, five gender-related areas of vulnerability can be derived from the literature, including:

1) Knowledge and abilities
2) Professional positions, division of labour, income levels and savings behaviour
3) Resource use, access and control
4) Health, insurance and security
5) Participation in decision-making, including politics

1) Knowledge and abilities

Women usually have central roles in household-related decision-making, and considerable power in influencing these decisions. In the Caribbean, the specific situation is that 40% of all households are headed by women (Massiah, 2006). Consequently, women are key decision-makers on the household level, though not on higher leadership and political levels, including community councils or groups, trade unions, political parties, religious bodies and other organisations (Massiah, 2006). It might thus be argued that women are currently key actors when it comes to climate change adaptation decision-making at the household level. The issues that need to be addressed at the household-level are various, including everything from the choice of location for housing, behaviour in extreme situations, or traditional knowledge (e.g., Lane and McNaught, 2009). While much of the knowledge and the abilities that are of importance to deal with extreme situations may be related to knowledge about the local environment, including physical resources and weather patterns, "expert" knowledge on climate change (or what could be termed a more formal understanding of when and why extremes occur, and how to adapt to these), would be of great importance to women. Many authors in various parts of the world have outlined the value of engendered local knowledge for adaptation, and greater recognition should be paid to this knowledge even in Caribbean contexts (e.g., Lane and McNaught, 2009; Terry, 2009).

2) Professional positions, division of labour, income levels and savings behaviour

In building on the previous section, the role of women in society deserves greater focus, as men usually occupy better professional positions, while women have more work to do, and have lower income levels. For instance, in Jamaica, Massiah (2006) reports that out of 14 trade unions, 12 have male Presidents and 10 have male General Secretaries, while of 31 publicly listed companies, all were chaired by men, and 30 had a male Managing Director. At the Board level, 90% of members were men. These examples illustrate the relative role held by women in terms of professional positions. With regard to the division of labour, women are likely to be in charge of much household work, with 40% of households being headed entirely by women, and a larger share of the remainder being likely headed by women as well. This puts greater pressure on women both in terms of household work, responsibility for children and older household members, as well as simultaneous engagement in income-earning activities. With regard to income levels, there is evidence that women are more often unemployed, have low-paying jobs, and may be more likely to lose their employment in times of economic recession (cf. Massiah 2006; Ellis, n.d.; Mendoza, n.d.; see also Ketwaru-Nurmohamed, 2008). There is no information regarding savings, but as women are typically the lowest paid in society, it can be reasonably assumed that they have fewer options to put aside savings. Nevertheless, if savings are put aside, it may often be women actually putting aside money (or other resources). So women may, through their savings/storage of food etc., build resilience in times of hardship. However, as yet, these interrelationships are little explored.

3) Resource use, access and control

Natural resource management is complex and of great importance in ecosystem management. More recently, much attention has also been given to the role of traditional ecological knowledge in creating ecological resilience through adaptive management. Berkes *et al.* (2000: 1251) state, for instance, in a review of the field that:

> *Case studies revealed that there exists a diversity of local or traditional practices for ecosystem management. These include multiple species management, resource rotation, succession management, landscape patchiness management, and other ways of responding to and managing pulses and ecological surprises. Social mechanisms behind these traditional practices include a number of adaptations for the generation, accumulation, and transmission of knowledge; the use of local institutions to provide leaders/stewards and rules for social regulation; mechanisms for cultural internalization of traditional practices; and the development of appropriate world views and cultural values. Some traditional knowledge and management systems were characterized by the use of local ecological knowledge to interpret and respond to feedbacks from the environment to guide the direction of resource management. These traditional systems had certain similarities to adaptive management with its emphasis on feedback learning, and its treatment of uncertainty and unpredictability intrinsic to all ecosystems.*

The role of women in adaptive management has yet to be explored, even though evidence would suggest that this should be a key issue to be researched (cf. Berkes *et al.,* 2000; Tomkins *et al.,* 2004). Notably, this would take into consideration the ecosystems on which most of the poor in developing countries depend in the Caribbean, i.e., coastal resources including wetlands, alluvial plain agriculture and coastal fisheries (Dulal *et al.,* 2009).

4) Health, insurance & security

There is a clear link between low income situations and limited capacity to adapt to extreme weather events. As women have been identified as belonging to low-income groups more often than men, health issues, including in the worst case risk of survival and death, are clearly a gender issue. Other aspects of health related to climate change include the spread of various vector-borne diseases, or heat stress. As outlined by Dulal *et al.,* (2009),

> *The incidence of non-vector-borne infectious diseases such as cholera, salmonellosis, and other food- and water-related infections may also potentially increase in the Caribbean, especially on islands such as Haiti and Grenada that have minimal public health care infrastructures and in remote, rural parts of larger countries such as Jamaica and Guyana.*

Other issues, such as security (see discussion below) are also linked to gender, but no research is available that has investigated this, particularly with a focus on the Caribbean (see, however, Ketwaru-Nurmohamed, 2008).

5) Participation in decision-making, including politics

Please refer to section 2 above, which details aspects of the professional positions women hold. From these discussions, it seems clear that women have disproportionally more power at the household level – generally because they are in charge of households while men seem to often live as singles, but they are, in relative terms, practically disempowered on all other participative levels. Note, that in more traditional communities, power distribution can be more uneven, with land use and housing permissions being granted by the male Tribe Chief or Chief Captain, and where women may not even be allowed to speak publically or to travel outside villages (Ketwaru-Nurmohamed, 2008).

These aspects illustrate that women are generally put at a disadvantage in dealing with climate change and disaster situations more generally. Integrating gender perspectives into all dimensions of the adaptation/mitigation agenda is an important step towards building adaptive capacity. Schalatek (2009: 5) thus emphasizes the need to engender climate change adaptation funds:

> *The experiences of mainstreaming gender in development efforts can be instructive, and tools developed in this context can likewise be adapted and utilized for making climate financing instruments more gender equitable. These include, but are not limited to gender sensitive indicators; gender analysis of project and program designs; gender-inclusive consultation, implementation, monitoring and evaluation; possible gender finance quotas or set asides via gender responsive budgeting processes applied to project funding; as well as mandatory gender audits of funds spent . However, the single most important tool in advancing fair and gender-equitable climate finance mechanisms– and apparently still the most illusive – is a political commitment on every level to take gender seriously in combating climate change.*

This view is also supported by Hemmati and Röhr (2009: 19): “The United Nations is formally committed to gender mainstreaming in all policies and programmes, and that should include policy-making processes relating to climate change. Yet gender aspects are rarely addressed in climate-change policy, either at the national or at the international levels”. Thus, there is an overall need to improve participation, both with regard to gender, and climate change adaptation more generally. As stated by Dulal *et al.* (2009), participation based on social equity values will help to incorporate stakeholder knowledge, skills, and opinions, while increasing compliance and support. Participative action will also mean to provide fora for identification and negotiation of conflicts, thus contributing to local empowerment.

Workshop results

Data concerning gender information has primarily been provided by two main parties: The Centre for Gender Studies, University of the West Indies (UWI) and the Bureau of Women's Affairs (BWA).

The UWI is concentrating its studies on the following points:

- Measuring how men and women are affected by disasters
- Monitoring the fact that women are more involved in subsistence farming, the service sector and are more likely to be affected by climate change impacts
- The impact of climate change and how women are more at risk of unemployment and job losses - should we target climate change messages to women?

The BWA are assessing issues of gender and climate change and have already held a regional conference. They are also involved in other workshops and future conferences.

Their focal points are:

- Embarking on 'gender mainstreaming'
- Seeking to integrate a gender perspective in all plans
- Tourism and gender issues
- Cross cutting

They have concerns regarding women as Centre Managers – and the role and safety of women in shelters, (vulnerable to sexual abuse).

In October 2005 an ECLAT report on Hurricane Ivan pointed to the natural disaster effects on women and children in Grenada. Following recent hurricanes and floods, and after dialogue with the UN and ECLAT concerning impact assessment, a similar study has been proposed for Jamaica.

It is essential to use a gender lens in assessment of vulnerability so that a response can be implemented to suit the differing needs of men and women.

Bahamas workshop

- Women are accessing higher education more than men, making them generally more aware of climate change.
- There are policy deficiencies in gender equality.
- Women play a lead role in households in disaster situations.
- Women have a stronger ability to influence children and young people than men do.

There is some gender information available from the Department of Statistics.

Women are accessing higher education more than men are, making them generally more aware of climate change. This also improves their access to financial support. There is a small difference in salary between men and women and there appears to be more female heads per household than male. The question is, are women being forced into dominant roles due to lack of male figures in order to fill these roles? Does this put too much pressure on the independence of women? Education is the key here. There are policy deficiencies in gender equality.

Laws and child support?

Women play a lead role in households in disaster situations. There are however important male roles in re-building infrastructure after these events.

Women have a stronger ability to influence children and young people than men.

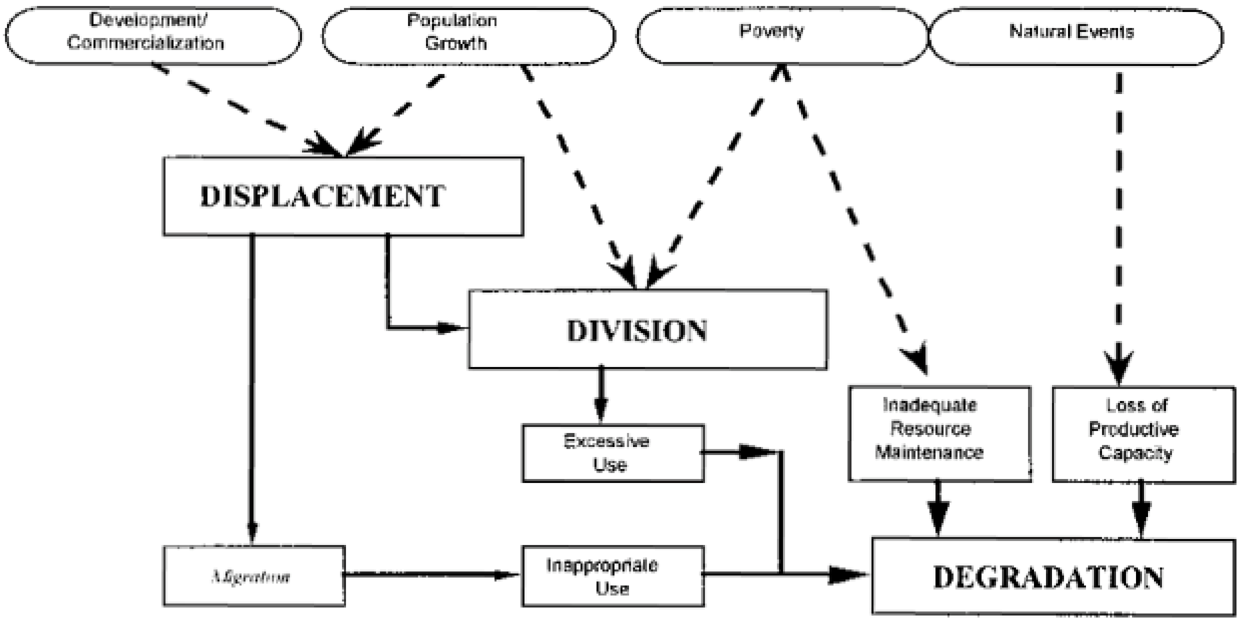
3.9.2 Poverty

The term "poverty" is contested in the field of development studies and is used here to denote national poverty lines, i.e., it makes no reference to the distinction of relative and absolute poverty. Dulal *et al.* (2009) provides a general ranking of Caribbean countries with regard to poverty levels, and concludes that Haiti and Suriname show the highest levels of poverty in the region, with an estimated 65% and 63%, respectively, of the populations living below the poverty line. The situation is better in a number of other countries, where the share of people below the poverty line is 30–40%, including Belize, Dominica, Grenada, Guyana, St. Kitts and Nevis and St. Vincent and the Grenadines. The situation is better in Anguilla, British Virgin Islands, St. Lucia, Trinidad and Tobago and the Turks and Caicos Islands, where between 20% and 29% of the population fall below the poverty line. Barbados has the lowest poverty rate of 14% (based on data for 1997), while Jamaica has a poverty rate of approximately 20% in 2002. (See also Senior and Dunn, n.d.). However, national poverty lines hide, that poverty rates are higher for women (e.g., Ellis, n.d.).

A commonality in all countries is that poverty tends to be more predominant in rural areas than in urban areas, even though urban poverty is usually more visible. As Dulal *et al.,* (2009) points out, rural poverty is characterized by lack of access to physical and financial resources, production support facilities, and social and physical infrastructure services such as electricity, water, sanitation, and roads and transportation. Urban poverty, on the other hand, would be characterized by high-density living, squatter settlements, and poor sanitation and waste disposal practices. Various researchers have presented models to understand how various factors interact in reinforcing poverty. Notably, climate change, and in particular extreme events, can trigger change that undermines livelihoods.

For example, Kates (2000: 14) model, derived from 30 case studies from all over the world of the underlying reasons for environmental degradation, outlines that locals in many rural areas may already face problems in maintaining access to natural resources for agriculture and herding or fishing, a process often related to population growth or competition for land due to development processes. Lands, water and other resources are divided and reduced through various processes, including sharing with children or sales to cope with extreme losses (crop failure, illness, death), social requirements (marriages, celebrations), or subsistence. Degradation is also incurred in excessive or inappropriate use (clearing, overgrazing, unsuitable cropping), failure to maintain or restore protective works (canals, dams, drainage, terraces) and the loss of productive capacity from natural hazards. Together, these culminated in three "major spirals of impoverishment and environmental decline": displacement, division and degradation. Kates (2000:14) concludes that "the very development-commercialization activities that displace poor people are precisely those that would constitute adaptive strategies to climate change...".

Figure 3.9-1: Model of the underlying reasons for environmental degradation



Source: Kates (2000)

In order to tackle poverty, it is important to understand these interrelationships, while considering the role of women. As Massiah (2006: 71) states, “In the area of poverty, we have learnt that poverty eradication programmes which are embedded in the prevailing global economic model provide little fundamental change to the circumstances of poor women”. Thus, the research carried out by both Kates (2000) and Messiah (2006) suggests that fundamentally new models for poverty eradication have to be found for the Caribbean, aiming at building adaptive capacity and resilience to climate change.

3.10 *International Climate Policy, Transport Costs and Tourism Arrivals*

Small island developing states (SIDS) rely heavily on air transport to support their tourism economies. As the international community has reached consensus that deep greenhouse gas (GHG) emission reductions are necessary over the next 25-40 years to avoid dangerous climate change, all emission generating economic sectors are being required to find ways to reduce emissions. While the contribution of air travel to global climate change is argued by the aviation industry to be small, air travel is growing rapidly in both developed nations and emerging economies. Under a ‘business as usual’ scenario, as projected by the aviation industry (Boeing, 2008), its contribution to global emissions would grow rapidly over the next 25 years as other sectors move to significantly reduce emissions (Kahn *et al.,* 2007). Because this strong emissions growth trend is in conflict with the emission reduction targets of international climate policy, several policy proposals are being considered to end the exclusion of international aviation from emission reduction frameworks (see Lyle (2009) for a recent summary). The European Union will become the first to include all flights in and out of its airports to account for emissions as a part of the EU cap and trade program. The United States is also discussing similar policies (Ljunggren, 2008). With the establishment of emission caps and eventual reduction targets for aviation, coupled with projections for rising global oil prices, the cost of travelling by air is anticipated by many experts to increase, which in turn, could impact demand for travel to island destinations. In addition, ‘travelers guilt’, due to the environmental impacts associated with air travel, has been intensified by media and published pieces condemning air travel because of its disproportionate impact on climate change (i.e., “Flying on holiday ‘a sin’, says Bishop” (Barrow, 2006) and “Oz Fears Jet-flight Guilt” (Bartlett, 2007)).

Climate policy to reduce GHG emissions within source market countries coupled with a potential increase in ‘travelers guilt’ are likely to be one of the most immediate challenges of climate change to tourism in the Caribbean. Other long-haul destinations (Australia, New Zealand) have expressed concern that the inclusion of aviation in climate mitigation policies could cause visitor numbers to decline as a consequence of associated increases in travel cost. A position paper by the Caribbean Hotel Association-Caribbean Tourism Organization (2007) states: “The immediate current threats are emerging as our major tourism markets seek to take urgent and decisive action to curb their own contributions to climate change. In so doing these developed nations risk curtailing the Caribbean region’s efforts to develop its societies and economies through its participation in the global tourism industry.”

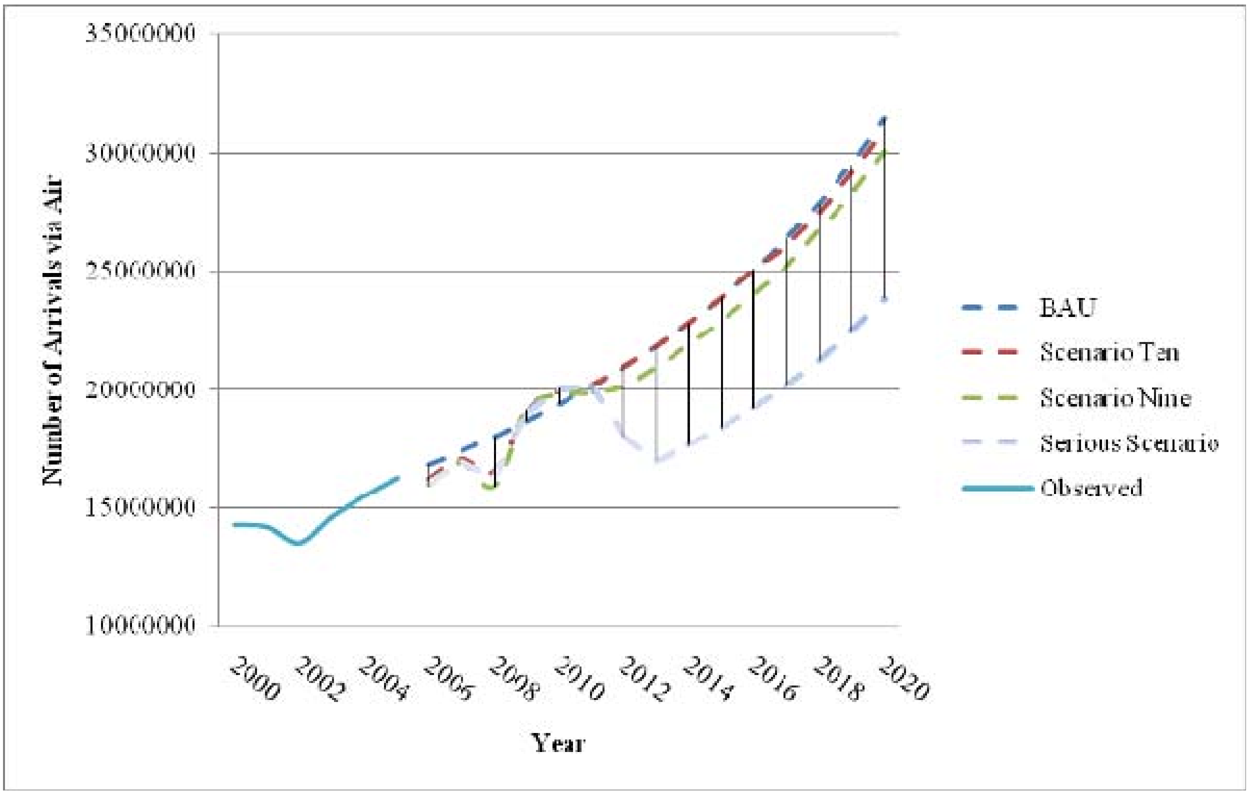
Pentelow and Scott (2009) developed an economic model to examine the potential impact of increased air travel costs associated with climate policy and higher fuel prices to the 20 Caribbean Community (CARICOM) members and associate members, plus three other large island nations which are popular tourist destinations; Cuba, the Dominican Republic and Puerto Rico. This study modelled the impact that the European Union ETS, as is expected to be implemented (with established emission caps and anticipated low and high market costs of carbon emissions - (Deutsche Bank, 2008; European Climate Exchange, 2009; Fortis, 2008; JP Morgan, 2007), an identical ETS in North America (US and Canada), and future oil price projections from the United States Energy Information Agency (low and high scenarios) would have for air travel costs and the resulting impact on tourist arrivals in each CARICOM nation through to 2020. A serious climate policy with much deeper emission cuts and carbon costs that are considered more indicative of the social cost of carbon (as estimated by - (Clarkson and Deyes, 2002; National Round Table on the Environment and the Economy, 2007; Nordhaus and William, 2005; Plambeck and Hope, 1996; Stern *et al.*, 2006; Tol, 2008) was also modelled, though such a policy framework is not likely to occur until after 2020. To determine the response of travellers to an increase in air travel prices, a range of price elasticity values from economic studies of air travel was used.

The results of this study indicate strongly which conditions could lead to the region experiencing the greatest (and the least) change in arrival numbers from air travel by the year 2020 versus a BAU scenario. On a whole, when climate policy and future oil prices are taken into consideration, the Caribbean region is expected to have fewer visitors in 2020 than would be projected under the 2020 BAU growth scenario. Figure 3.10-1 shows a 2000-2020 time series for a BAU scenario, scenarios of the minimum and maximum reductions in arrivals due to anticipated climate policy and fuel prices, and the serious climate policy scenario. Region wide arrivals were projected to decline by 1.3% to 4.3% in 2020 versus a BAU growth scenario. While climate policy and increased fuel prices are expected to have a negative impact on tourist arrivals, arrivals are still projected to double over the next decade. The ‘serious’ climate policy scenario had much greater impact on arrivals at 24% below BAU.

Importantly, because of the distances from main international markets, the composition of charter tourist arrivals and the climate policies in these markets, the impacts of climate policy and fuel prices on arrivals differed among the Caribbean nations in the study. In all of the scenarios shown in Figure 3.10-1, The Bahamas was found to be among the most vulnerable nations, with arrivals declines of 1.9% to 6.9% from BAU and a significant reduction of 42.9% under a serious climate policy scenario.

The modelling clearly showed that the potential impact of global climate policy and future oil prices on consumer demand to The Bahamas must be taken seriously, particularly beyond the negotiations for the immediate successor to the Kyoto Protocol. Analysis of the policy implications of the COP-15 negotiations in Copenhagen on tourism should be a priority for future analysis, including a more detailed examination of the specific source markets of Eleuthara, their price elasticity and options for reducing exposure to climate policy by focusing on less energy intense markets.

Figure 3.10-1: Projected Growth in Tourist Arrivals to the Caribbean by Air



3.11 *Climatic Resources for Tourism*

Numerous studies emphasize that climate, particularly temperature, is one of the most important resources of a tourist destination and a principal motivator for many travellers (Mintel International Group 1991; Morgan *et al.,* 2000; Lise and Tol, 2002; Gomez-Martin, 2005; Hamilton and Lau, 2005; Lohmann and Kaim, 1999; Gössling *et al.,* 2006; Scott *et al.,* 2008). One of the principal reasons behind the popularity of the Caribbean is the demand for a predictable sunny and warm destination, especially during the winter months in high latitude source markets. With the onset of climate change, this climatic parameter of tourist destinations will change, leading some scientists and the media to claim that some destinations, including many Caribbean islands, could become "too hot" for tourist comfort during peak tourism seasons and a resultant decline in visitation. Tourists have the greatest capacity to adapt to the impacts of climate change, with comparative ease and freedom to avoid undesirable climatic conditions by either altering the timing of their trip or avoiding the destination altogether (UNWTO-UNEP-WMO, 2008). It is therefore imperative to understand what climatic conditions tourists deem as unsuitable for a holiday and if such conditions would occur regularly as a result of projected climate change.

A recent survey with European tourists sought to determine the perceived range of optimal temperatures for tourist satisfaction for beach tourism, as well as thresholds for unacceptably cool and unacceptably hot conditions (Rutty and Scott, 2009). Three classifications for beach holiday temperatures were defined by the majority of responses (>50%): optimal between 27°C and 32°C, unacceptably cool when less than 22°C, unacceptably hot when over 37°C.Transition zones were observed between ideal and unacceptably cool/hot.

To evaluate the suitability of climate conditions for beach holidays in The Bahamas, the three temperature classifications have been compared with the monthly average daytime high temperatures from the baseline period of 1970-99 and under the median temperature scenario for the 2020s, 2050s, 2080s, and the maximum warming scenario for the 2080s (as set out in section 2.3) (Figure 3.11-1). Currently no month has daily maximum temperatures that are in either the unacceptably hot or cool range, with April to October in the optimal zone. Under all climate change scenarios, no month has daily average maximum temperature projected to be in the unacceptably hot range. Through the 2050s and even 2080s, the number of months with average daytime maximum temperatures in the optimal range remains the same (7), but the months in the optimal temperature range change. As temperatures warm, Feb, March and Nov enter the optimal range, while the summer months of July and August and eventually June and September enter the transition zone between optimal and too hot. The impact of projected warming temperatures in The Bahamas on tourism demand is therefore expected to be minor.

Of greater potential consequence to tourist arrivals in The Bahamas, are the projected changes in climate in major source markets. In high latitude markets, cold winter temperatures are a strong motivator for travel to the Caribbean and other sunshine destinations (Mintel International Group, 1991; Hamilton and Lau, 2005; Lohmann and Kaim, 1999). The relationship between average monthly temperatures in some regions of the US and Canadian markets and demand for tourism (arrivals) in Jamaica is highly correlated (see Figure 3.11-2 for the central Canada market), but weakens with latitude (see Table 3.11-1 for all Canadian regional markets). Travel to the Caribbean from markets like New York, Chicago, and Toronto are strongly related to cold temperatures, while travellers from markets like Miami are motivated by other factors and there is a weak correlation with temperature. Using the current temperature-demand curves, the implications of projected future climate change in major source market regions was examined for the central Canadian market. The blue diamonds and regression line represent the current temperature-arrivals demand curve based on 2001-2007 data. The red circles represent the projected monthly temperatures in the 2050s (Had-Gem1 A1B scenario) and illustrate how demand declines as average monthly temperatures warm substantially in SON, DJF, and MAM shifting these months down the demand curve. In each of the Canadian regional markets, projected warming in the winter and early spring, late fall months is similarly anticipated to reduce demand for sunshine holidays in The Bahamas.

Figure 3.11-1: Ratings for Beach Tourism and Average Daily Maximum Temperature

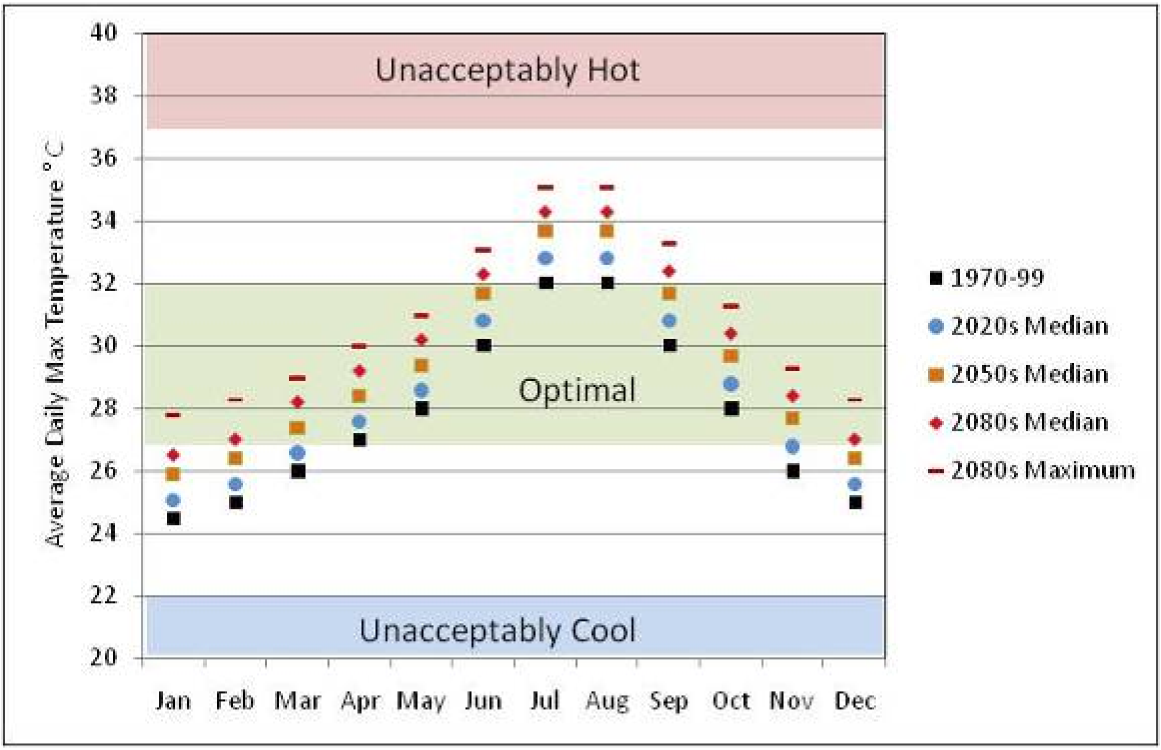
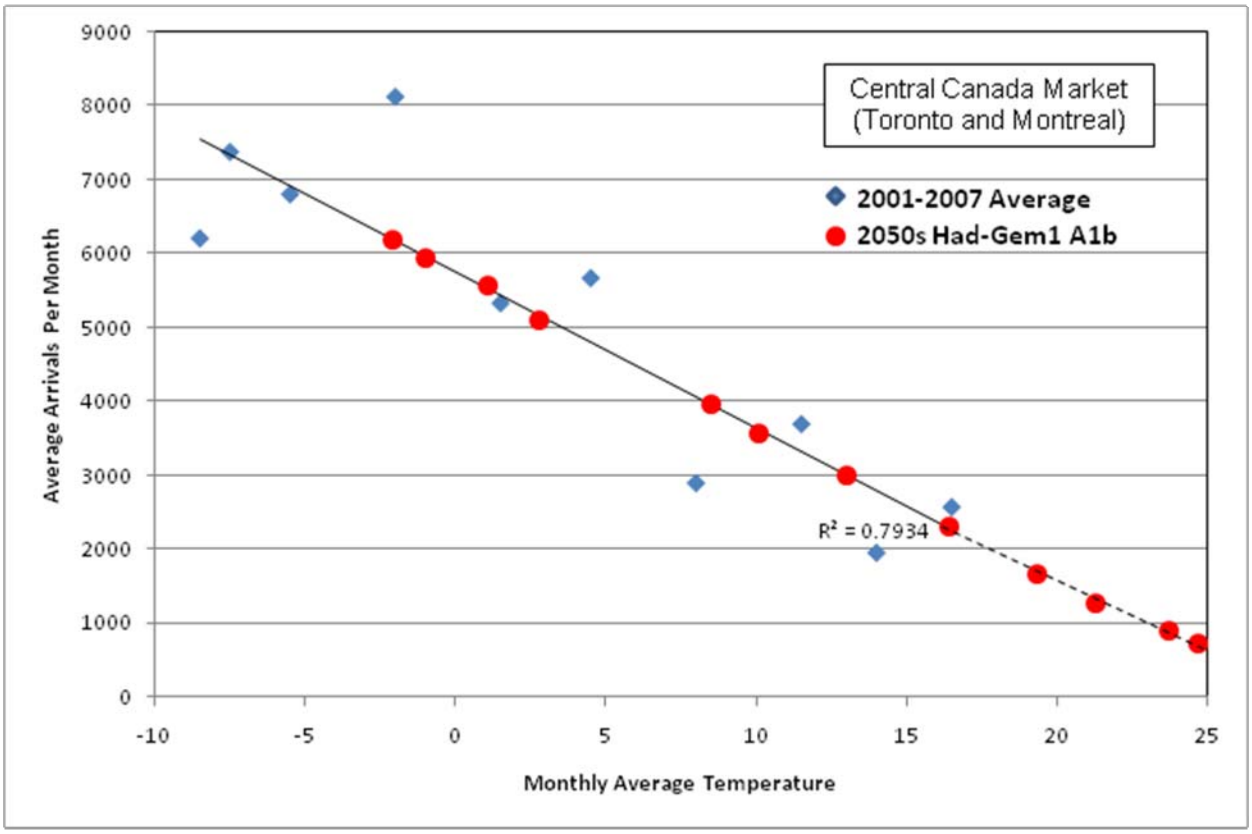


Figure 3.11-2 Relationship between Monthly Temperature at Source Market and Arrivals to Bahamas



Source data 2001 to 2007 from Bahamas Tourism

Table 3.11-1: Relationships between Monthly Temperature at Source Markets and Arrivals to Bahamas

Source Market	R^2 (all data 2001 to 2007)
Western Canada	0.79
Prairie Canada	0.83
Central Canada	0.79
Northern Canada	0.83

3.12 *Conclusion*

The previous sections have outlined some of the interrelationships of poverty and gender issues. Overall, poor women have been identified as one of the most vulnerable groups in society, whose livelihoods may be threatened by climate change. However, three more vulnerable groups in society may be added to this, including the elderly, children and indigenous people or ethnic minority groups.

4. ADAPTIVE CAPACITY PROFILE

4.1 *Introduction*

Information on the following factors was gathered to reflect adaptive capacity:

- Resource availability (financial, human, knowledge, technical)
- Institutional and governance networks and competence
- Political leadership and commitment
- Social capital and equity
- Information technologies and communication systems
- Health of environment

The stakeholders at the workshop, including the Tourism Development Group, listed the following key challenges to address climate change:

- Will – political and social
- Education
- Financial
- Technical
- Human resources

They stated that there is insufficient knowledge about climate change and that more needs to be gained at local level. There are some experts dealing with crisis situations but further training is required. There is also a lack of weather stations and consequently a lack of sea level gauging. With regards to the financial situation there is no budget for dealing with climate change – it requires external funding. There is an adaptation deficit. The political will is there but constrained. Climate change is viewed as a long term issue which can be delayed. There is need for improvement in collaboration between organisations.

Adaptive capacity is the ability of a system to evolve in order to accommodate climate changes or to expand the range of vulnerability with which it can cope (Nicholls *et al.*, 2007). Many small island states have low adaptive capacity and adaptation costs are high relative to GDP (Mimura *et al.*, 2007). Overall the adaptive capacity of small island states is low due to the physical size of nations, limited access to capital and technology, shortage of human resource skills and limited access to resources for construction (IPCC, 2001). Low adaptive capacity, amongst other things, enhances vulnerability and reduces resilience to climate change (Mimura *et al.*, 2007). However, Mimura *et al.* (2007) go on to suggest that very little work has been done on adaptive capacity of small island states. Despite this, even a high adaptive capacity may not translate into effective adaptation if there is no commitment to sustained action (Luers and Moser, 2006).

4.2 *Resource Availability*

The economic condition of nations and groups is a key determinant of adaptive capacity (Kates, 2000). Generally, wealthy countries are better prepared to bear the costs of adaptation to the potential impacts of a changing climate (Burton, 1996). Poverty is related directly to access to resources and the process of marginalisation (Kelly and Adger, 1999). Developing countries possess a lower adaptive capacity as a result of a greater reliance on climatic resources (Schelling, 1992; Fankhauser and Tol, 1997). Managing natural resource systems with the added stresses associated with climate change posses a challenge for socio-economic systems and negatively affects adaptive capacity (Tompkins and Adger, 2004). The most vulnerable communities such as indigenous group, farmers, fishing community, and tribes are tied to their local resources and local social dynamics (Dulal *et al.*, 2009). Reducing demand for resources such as water can improve adaptive capacity (Smith and Lenhart, 1996). However, people may also have developed a variety of adaptation strategies to cope with the climatic variability and change. Adaptive capacity can be strengthened through the application of traditional knowledge (Mimura *et al.*, 2007).

Dow (1992) describes poverty as "a rough indicator of the ability to cope". Pelling (1998) found that, in Guyana, social and political assets play important roles in shaping access to local, national and international resources for environmental management. Marginalised groups with limited social resources (women, children, the elderly, the economically poor) were excluded from local decision-making (Pelling, 1998). Poorer households will have a lower adaptive capacity as they will be dependent on a narrower range of resources and income sources (Kelly and Adger, 1999). Changes in population and income will also affect resource use (Smith and Lenhart, 1996). Lack of access to resources is considered as one of the major barriers to adaptation (Dulal *et al.*, 2009). Kelly and Adger (1999) report that resource availability and the entitlement to use these resources determines an individuals or groups vulnerability to climate change. More specifically, the adaptive capacity of the tourism sector is inhibited by the rapidly growing coastal population and coastal urbanisation.

A common constraint for most small island states is the lack of in-country adaptive capacity (Mimura *et al.*, 2007). Given that small island states are small, pooling of resources through regional or national cooperation would be an effective way to increase adaptive capacity. For example, the GEF-funded *Caribbean Planning for Adaptation to Global Climate Change* project was implemented by 12 Caribbean states. In The Bahamas, resources have been made available to address the challenges of climate change. The College of the Bahamas (COB) has a good knowledge base and a Small Island Sustainability Degree Program. The COB database online is available to general public.

The consensus is that there is knowledge in The Bahamas but it is inadequate across sectors. Generally, when people think of climate change they may automatically think of hurricanes as opposed to global temperature change. Within The Bahamas, there is also a lack of technical resources and agencies often have to bring in foreign consultants and engineers from abroad to do the work for them. Resources may be locally available but they remain too expensive. Training local people is essential for capacity building, so Bahamians should be involved when foreigners come to do research and consultancy work.

There is a lack of skills in information technology especially in GIS modelling. Any GIS data should be more available with all information collected from research permits submitted to Bahamas National GIS for the benefit of the government and the ministry of environment. There is an additional need for improved data collection in general. For example, meteorological data remains undigitised as this requires investment and staff to process it. There are a limited number of skilled people and retaining them is a problem as once they are trained they tend to move on the 'greener pasturers'.

Some resources exist but these are focused on crisis situations, modelling and coastal defences. These exist in the Department of Meteorology and the National Emergency Management Agency (NEMA). Information can also be accessed through the Caribbean Community Climate Change Centre.

Poor funding is currently given to climate change adaptation. It is the responsibility of the Bahamas government to provide funding for climate change adaptation (maybe through, taxation, down payment for environment infractions). BEST manages to get some funding from GEF and UNDP. The main difficulty is the application for international grants. The Bahamas does not have enough grant writers and many grants are turned down when requested through EU, WB, IDAB. Proposals have to be written on time and are time consuming and difficult. Other Caribbean countries submit a higher number of applications compared to The Bahamas.

The *Second National Communication Project*, currently in progress, is focused on climate change and what contributions can be made to mitigate the effects. Once this project is completed a determination will be made as to how much funding may be allocated. The Government has contributed in kind to the project in terms of staffing.

4.3 *Institutional and Governance Networks and Competence*

Strong, stable, and efficient institutions and good governance enhance the adaptive capacity of the community, society, or the nation (Dulal *et al.*, 2009). Institutions in many wealthy industrialised countries are robust (Handmer *et al.*, 1999). When compared to a country with good organization and preparedness, a disorganized and unprepared government also means a lower adaptive capacity for a country (Vincent, 2007). Local institutions have three principle roles in adaptation: structuring impacts and vulnerability; defining individual and collective responsibility to adaptation; and defining relation with the external agencies (Agrawal, 2008). Handmer *et al.* (1999) go as far as to suggest that institutional capacity and human behaviour are more important for adaptive capacity than biophysical impacts. Failure to invest in adaptation may leave a nation poorly prepared to cope with adverse changes and increases the probability of severe consequences (Smith and Lenhart, 1996).

Institutions are, perhaps, most significant at the national level. For example, in addition to availability of financial resources, adaptive capacity also reflects the degree of institutional capacity and organizational sophistication in targeting those resources effectively to the areas and groups of people that are most vulnerable (Kasperson and Kasperson, 2001). Regardless of poverty issues and the use of resources, it is the formal political institutions that devise and implement the legal enforcement of property rights (Kelly and Adger, 1999). Formal governance institutions are influenced by scientific consensus, exposure to specific hazards and formal or informal group action within their jurisdiction (Tompkins, 2003). However, inclusive institutions and the sharing of responsibility of natural resources required to increase climate change adaptive capacity, goes against the dominant hierarchical institutional forms of most Governments (Tompkins and Adger, 2004).

Within The Bahamas, the following are the key decision making authorities relating to climate change:

- Department of Meteorology
- Ministry of Environment
- Ministry of Works
- Department of Agriculture
- Department of Marine Resources
- Ministry of Finance

They are all government agencies and are controlled by the Ministers of Parliament. Of these, the Ministry of Environment is the best agency to manage the adaptation process and budget. However, there is a challenge to encourage collaboration between agencies and ministries. Addressing data collection and communication issues needs greater understanding and education in order to recognise its importance.

Many of the government organizations are doing work but more of a cohesive effort is needed. They need a partnership and a framework. A private and public partnership could be implemented. BEST commission is the focal point for environment issues but they can not make decisions as they are made by government.

There are a number of committees, within The Bahamas, that are working on climate change adaptation including those on invasive species, climate change, national coastal awareness and NEMA (National

Emergency Agency). This, however, creates a challenge as there is information that must be shared and approved and it must be done by everyone. Furthermore, more coordination is needed. Bahamas investment authority should be included everywhere.

Generally stakeholders work together on development planning and management. Various agencies are responsible for responding to natural hazards:

- Land hazards – Department of Environmental Health Services
- Sea – Ministry of Transport (Port Department more specifically)
- Disease – Ministry of Public Health
- Hurricanes – National Emergency Management Department (NEMA)

At the household level, adaptive capacity depends on factors such as knowledge base, which enables people to anticipate change and identify new or modified livelihood opportunities, and their access to resources required to maximize their livelihood opportunities [Vincent, 2007].

There are approaches to increase the adaptive capacity of various countries. For example, the UN-Habitat‘s Sustainable Urban Development Network (SUD-NET) is a global initiative advising and providing capacity-building support to local authorities. The Cities in Climate Change Initiative (CCCI), a component of SUD-NET, supports the improvements of governance structures, tests innovative financing, and advises on sustainable construction materials to enhance the adaptive capabilities of local government. The CCCI is operational in a number of Caribbean towns and cities.

4.4 *Political Leadership and Commitment*

There is growing evidence that adaptation and mitigation will not be considered separately in global policy and development aid, but rather as a combined strategy. Consequently, there will be a demand for developing countries to contribute to reductions of greenhouse gases through projects that simultaneously address poverty eradication and adaptation. Schalatek (2009:5) remarks that according to the UNFCCC’s Bali Action Plan, financing for climate change will have to fulfil a set of non-negotiable criteria, i.e., projects will have to be adequate, sustainable, predictable, as well as new and additional, i.e., not replacing Overseas Development Assistance. This will have the purpose of securing commitment by the developing world to contribute to mitigation. On top of these demands, the gender dimension might become more relevant in the future. Governments and decision-makers need to be aware of these ongoing changes in global climate negotiations, as they are of great relevance for national policies seeking to support various economic sectors. Tourism, in particular, as a highly carbon-intense sector, might be at a crossroads given these new realities of global climate policy.

Workshop
It was stated that there is reasonable political support for adaptation to climate change. This is evident in the creation of the Ministry of Environment in 2008. They are aware that further political support is required.

The main challenge in The Bahamas is how the data becomes policy. The Minister of Environment has to take the data to the policy makers and the cabinet. Any future development should respect the policy. The Bahamas are lacking a national plan, so many things are happening but a policy framework could assist to pull everything together.

All levels of political support need to be strengthened. Nationally there is some political will; this is evident through the facilitation of environmental protection and mitigation framework such as climate change policy development. However, there is no regional or local political will at any scale for adaptation.

It was felt that the different departments and ministries were working together in a trans-disciplinary manner. This is evident in the formation of the National Climate Change Committee which transcends across governmental and non-governmental agencies.

4.5 *Social Capital and Equity*

As has been outlined in the previous sections, poor people, and in particular poor women, are the most vulnerable to extreme climate events. This is a result of their lack of financial resources and savings, the insecurity of their employment – particularly in tourism and agriculture -, their living in often more hazardous locations with greater exposure to floods, windstorms and landslides, and the general quality of housing, which may often not conform to codes for disaster-risk reduction (Dulal *et al.,* 2009). Increasing inequality within a population can heighten collective vulnerability (Kelly and Adger, 1999). These factors need to be considered when discussing social capital and equity.

Social equity is based on fair, just and equitable sharing of and access to resources. Dulal *et al.* (2009) outline four rules to achieve this:

(i) Access by all members of society to due process, equal protection by law and equal rights from existing policies and programs.

(ii) Access to democratically managed goods and services and the right to benefit from such.

(iii) A right to quality and consistency in existing goods and services provided in a democratically managed system.

(iv) Policy outcomes that determine whether policies and programs have the same impact for all groups and individuals served.

Consequently, climate policies should work in particular for the benefit of poor groups, thus contributing to greater social equity. As many authors have emphasized, pro-poor policies, for instance in tourism, have often been successful in creating jobs and employment, but the already wealthy have usually profited disproportionally from these policies as well (Schilcher, 2007). Adaptation politics should consider this, and ensure that they do not “accentuate or perpetuate” already existing social, gender, economic or cultural inequities (Dulal *et al.,* 2009). Policies must be improved or developed to simultaneously promote socio-economic development and social justice (Kasperson and Kasperson, 2001). Policies must also emphasize improving human skills through education and training; improving employment opportunities; improving access to resources; increasing income generation opportunities and improving healthcare (Dulal *et al.,* 2009). It is imperative that community policy includes and values everyone (Dulal *et al.,* 2009).

Kelly and Adger (1999) suggest that capacity is determined both by individual vulnerability (which includes access to resources, diversity of income sources and the social status of the household within the community) and the collective vulnerability of a social grouping determined by institutional and market structures. Based on a study conducted in Trinidad and Tobago, Tompkins and Adger (2004) found that community-based management enhances adaptive capacity. This was achieved by building networks that are important for coping with extreme events and by retaining the resilience of resources and ecological systems (Tompkins and Adger, 2004).

The ProVention Consortium (a global partnership on disaster risk reduction), in collaboration with the International Federation of Red Cross, hosted a workshop in Trinidad and Tobago (2008), with the objective of developing a Caribbean Programme of Action for strengthening community resilience and local adaptive capacity to the changing climate.

4.6 *Information Technologies and Communication Systems*

The lack of appropriate technology and trained personnel, financial limitations, and legal institutions may all restrict a nation's ability to implement adaptation measures (Scheraga and Grambsch, 1998). Adaptive capacity depends on the availability of, and access to, technology (Burton, 1996). Adaptive capacity is largely dependent on development status (Nicholls *et al.*, 2007). An individual's, community's and a nation's ability to access and develop technologies will affect adaptive capacity. Greater access to wealth and technology generally increases adaptive capacity (Yohe and Tol, 2002). This includes training and skills. If a nation has a lack of skilled personnel they will have a lower adaptive capacity and have less ability to implement adaptation options (Scheraga and Grambsch, 1998). It is important to ensure that systems are in place for the dissemination of climate change and adaptation information nationally, regionally and locally. Whilst institutional networks are an important influence on adaptive capacity, the communication and information transfer linkages between formal governance institutions is also critical (Tompkins, 2003).

As reported in a previous section, there is currently a lack of resources including skills and knowledge in information technology, including GIS mapping, and that there is also poor data collation within The Bahamas. Any available information should be put into the public domain and data sources should be verified to ensure good quality. Each Caribbean country should also have its own data distribution centre. There is a lack of peer reviewed papers on small islands – mainly grey literature, which is not easy to access.

One of the responses to deal with skills and knowledge sources is overcome by using foreign experts and consultants. However, this does not solve the issue. It has been suggested that there is a need to promote voluntary assistance to overcome human resource deficit (i.e., internships). Visiting scientists need to ensure that their results are returned to the governments, departments or institutions so that they can be used more widely within the country and surrounding areas.

Understanding adaptive capacity cannot be divorced from the issue of knowledge and power (Brown, 2009). However, Galvin (2009) suggests it is wrong to focus too much attention on top-down technology-based adaptations that address specific impacts. Instead, approaches and initiatives that increase human capacity to respond to climate change threats in creative and innovative ways should be encouraged (Galvin, 2009).

A GEF-funded project entitled *Caribbean Planning for Adaptation to Global Climate Change (CPACC)* supported Caribbean countries to prepare for the adverse effects of climate change. As a result of the project, amongst other things, all countries now have improved access and availability of data. Following this, the Canadian International Development Agency provided a grant to further capacity building efforts. The *Adapting to Climate Change in the Caribbean* project included public education, strengthening technical capacity and the development of adaptation strategies for water, human health and agriculture.

4.7 *Health of Environment*

Due to their size and narrow resource base, small island states have a lower capacity to deal with natural and/or environmental disasters. If this is coupled with a decline in traditional coping mechanisms, then adaptive capacity to climate change impacts will be further reduced. Existing threats to natural ecosystems and species diversity will affect ecosystem resilience and capacity to adapt to climate change (Scheraga and Grambsch, 1998). Fragmentation of habitat reduces adaptive capacity. Natural and manmade barriers, such as roads and bodies of water, and agricultural land may block the migration of species (Scheraga and Grambsch, 1998). Sensitive systems cannot be considered independently (Scheraga and Grambsch, 1998).

Adaptive capacity is reduced if agriculture is based on single monoculture crops, as these and the surrounding environment is then more vulnerable to effects of climate change. In addition, conversion of land for human activities (e.g., farming, urban settlements) can interfere directly with plant dispersal and species movement (Scheraga and Grambsch, 1998).

In most Caribbean islands, more than 50% of the population live within 2km of the coast (IPCC, 2001). With a limited amount of space and projected sea-level rise, there will be increased competition for land. Current pressures are likely to adversely affect coastal ecosystems and their ability to cope with additional climate changes (Nicholls *et al.*, 2007).

Wetlands provide a range of essential goods and services and have a significant role in protecting both coastal and inland resources from climate change. Tropical island nations are highly dependent on coastal ecosystems and the ecosystem services that flow from them (Tompkins and Adger, 2004). Coastal development negatively affects adaptive capacity with regards to sea-level rise. Approaches designed to promote shoreline stabilization, such as sea walls, can also have a detrimental impact (Smith and Lenhart, 1996). However, maintaining and preserving coastal wetlands is a natural approach to sea-level rise and will increase an areas adaptive capacity. Wetlands can also improve water quality and flood control. The implementation of any adaptation options to protect shorelines will involve significant financial commitments. Bijlsma *et al.* (1996) suggests that for countries such as Antigua, Guyana and St. Kitts-Nevis, the costs involved are substantial compared to the nation’s GNP.

4.8 *Conclusion*

Adaptive capacity is determined by complex inter-relationships of a number of factors at different scales and is multidimensional in nature (Dulal *et al.*, 2009). The determinants are not independent, but nor are they mutually exclusive. Enhancing adaptive capacity will only be successful when it is integrated with other policies such as land-use planning, environmental conservation and national plans for sustainable development (Sutherland *et al.*, 2005). Sustainable development can enhance adaptive capacity and increase resilience. Policies that enhance social and economic equity, reduce poverty, improve environmental management and increase the quality of life, will advance sustainable development and, therefore, strengthen adaptive capacity (Nicholls *et al.*, 2007).

5. CONCLUSION, RECOMMENDATIONS and PLAN FOR ACTION

5.1 *General Action Points*

The next step in the process of policy and strategy development and implementation is to develop an Action Plan for destinations and for each nation in the Caribbean Basin. The following Summary Action Plan represents the first stage in that process and concludes the outputs from the seed funding stage of the DFID funded phase of CARIBSAVE.

Equity and gender issues should be of key relevance in developing national and regional climate change adaptation strategies in the Caribbean. Consideration of other stressors such as population growth, poverty, health and resource depletion are also important as climate change will interact with these in uncertain and cumulative ways. All strategies that are developed will have to be specific, considering power structures and cultural issues (e.g., Nelson and Stathers 2009). With regard to policy action, several key issues have been emphasized in the literature. Dulal *et al.* (2009) suggest that policy makers will need to proceed based on best practice examples. They provide three examples, addressing housing, transportation, and livelihoods, to improve social equity and climate change adaptive capacity (Table 5.1-1). With regard to housing, Dulal *et al.* (2009) suggest that governments support family housing, with the need for new residential buildings to consider low-energy options to reduce energy use. Their transportation policy suggestion is to subsidize fuel for private cars, which must be seen, however, as a measure encouraging greenhouse gas emissions, and is thus modified in the table to address public transport. Finally, with regard to livelihoods, they suggest investments in cleaner industries, eventually with a focus on environmental technology. While these are not mentioned by Dulal *et al.* (2009), solar power, including both electricity generation and warm water provision, groundwater-based cooling technologies, as well as biogas must all be seen as holding great potential for the islands, and in particular for tourism.

Table 5.1-1: Policy action examples for the Caribbean

	Policy Action	Impact on social equity	Case example
Housing	Government commitments to provide family housing for persons classified as low income groups	Reduces risk of poor families squatting in climate vulnerable areas such as coastal marshes	Tax breaks for residential and commercial installation of solar heaters and solar panels in Barbados; commitment to utilize low impact building materials in government housing projects in Dominica, Jamaica and other islands
Transportation	Improvement of public transport system, eventually provision of national subsidies for public transport to maintain affordable prices	Maintains transport links to workplace	
Livelihoods	Invest in development of cleaner industries and the human resources to be employed in these industries	Access to specialized education opportunities for new “green jobs“	Development of national education programmes and institutions. For example new national universities in Trinidad and Tobago and the French Antilles have been established over the last five years with heavy emphasis on “green skills“ and environmental technology

Modified from Dulal *et al.* (2009)

Recent reports also make a number of suggestions to link disaster risk management to gender issues. For instance, Ellis (n.d.) and Mendoza (n.d.) recommend to revise disaster policies to make them gender sensitive. This might also include gender training and gender-sensitive Management Information Systems, Risk Assessment, and Early Warning Systems.

There are several significant gaps in regional and local data regarding vulnerable social groups, without which policymakers will be unable to develop policies and adaptation action plans that fully meet the needs of these constituents. For instance, it will be very instructive if we can learn about the impacts that past hurricane catastrophes have had on rural and traditional livelihoods and community structures. Another area of interest revolves around the important economic and community activity of community based tourism. Traditionally rural livelihoods have revolved around some combination of farming, fishing, non-timber forest product harvesting and processing, all of which can lead to resource depletion if not adequately managed. Community-based tourism is the only solution that most Caribbean islands have come up with as alternatives or complements to these activities. Climate change is likely to threaten the tourism attractions on which this depends. Apart from the examples listed above, there is a need for research on the process of social adaptation in SIDS, including how to develop sustainable and results oriented projects to assist marginalized communities and equitable ways to build policies and institutions. This type of research would facilitate joint learning and consensus building among parties about policy responses in specific contexts for the purpose of developing practical policy options [41] understood and supported by the participating communities. Adaptation is as much about changing attitudes and behaviours as finding technical solutions. The development of adaptation planning processes and best-practices are context specific. The tools and methods adopted to facilitate adaptation should create opportunities for participation and cater the needs of vulnerable population.

5.1.1 Completing the Adaptation Cycle

Part of the process in fully developing policies and strategies involves the implementation of the ‘Adaptation Cycle’ (Annex 1). In accordance with the terms of reference of the seed funding project, the ‘Adaptation Cycle’ has been successfully started by the completion of stages 1 –3: ‘engage stakeholders’; ‘define the problem (screening assessment for vulnerability)’; ‘adaptive capacity assessment’. In addition, and beyond remit of the seed funding project, the finalisation phase of stage 4 in the ‘Adaptation Cycle’ has also been reached: ‘identifying adaptation options’. A fundamental Action now is to complete the remaining stages in the cycle. The cycle towards effective implementation of adaptation strategies and completing one full ‘round’ of the cycle includes the following stages: ‘evaluate adaptation options and select course of action (establish evaluation criteria and weighting)’; ‘implement adaptation’; and ‘monitor and evaluate adaptation’. This Action of completing the final four stages of the cycle will include taking the work conducted to date and, through semi-structured interviews, focus group meetings and electronic communication, re-engaging with the key stakeholders in the identified key sectors (water, energy, agriculture, health, biodiversity, infrastructure and settlement, and comprehensive disaster management). The focus will be on the dominant issues as identified in the work to date and on the adaptation options already identified. Further collaborative work will be conducted surrounding these actions and topics. Workshops will be facilitated to work through problem identification, the adaptation portfolio, the ranking of options and a short list will be agreed upon to proceed with and funds will be allocated accordingly. In addition to the key stakeholders from the seven identified sectors, work will be conducted at two specific echelons within The Bahamas; government ministries will be involved in policy and strategy development and implementation and community stakeholders will be involved in the development and implementation of community-based adaptation strategies. This work will inform and build capacity in order to be able to implement strategies right across the key sectors and involving all levels of society. Other destinations, nations and communities will also benefit as many will face similar challenges and will respond by even better implementation of appropriate strategies

Nature of Action: Combination of Government Policies and Community Based-Adaptation Strategies

5.1.2 Climate Data Collection and Collation

The Caribbean, The Bahamas included, is a region very short on observed climate data. The issue of data access and circulation was raised repeatedly at the workshop in The Bahamas as a significant limitation in impact/vulnerability assessment and adaptation planning and is clearly a very important component of capacity building. There is however, a large volume of data that is held by individual meteorological departments that is currently not used because it is either (a) not yet digitised (b) not homogenised or (c) simply not passed on. It is a propose Action for The Bahamas that the climate dataset should be thoroughly assessed if necessary and a new one constructed or the existing one refined. This will include the collection and collating as much existing data as possible for The Bahamas. This will involve:

(a) seeking out undigitised data that can be added to the record
(b) digitising data
(c) homogenising data
(d) gridding data
(e) blending the station data with satellite records to fill in geographical gaps
(f) making the datasets freely available via the internet

This Action will build capacity, contribute hugely to local climate change impact studies, as well as climatological studies, hydrology, agriculture and also be very useful to the global climate change community, contributing to global detection and attribution studies by assisting to fill in the current regional data gap.

Nature of Action: Government Policy overtones due to need for cross-ministerial cooperation and collaboration

5.1.3 Application of Vulnerability Indices

This sector will be further examined and developed whilst undertaking the Country profile.

5.2 *Infrastructure and Settlements*

5.2.1 Coastal Erosion in Dune Areas

Sand Dunes on Eleuthera and Harbour Island are subject to coastal erosion and are at threat to more severe erosion as the coast experiences sea-level rise and increased incidence of storm surge. Action must be taken to protect the dunes; re- vegetation of dunes is a critical factor in the restoration and protection process. Plants such as Sea Oats should be used to strengthen the dunes; Sea Oats form roots that can grow to 25 ft (8 m) these roots can hold the dunes together.

Nature of Action: Community Based-Adaptation Strategy with potential Policy overtones due to requirement for funding for plants

5.2.2 Implementation of Sandwatch Projects

To gather data, to better manage the erosion and condition of the beaches and water around Eleuthera and to build capacity, transfer skills and heighten awareness within communities from children upwards, a Sandwatch project is proposed. This project is student-centred in its design and implementation. A central project strategy is training participating students in basic scientific observations and measurement, providing data which can then be analysed using mathematical, computing, and language skills. This training is provided in the context of environmental management and sustainable development, as the students use the information in the implementation of projects to help solve specific environmental problems. The students are asked to involve their parents and communities in their projects in an effort to increase environmental awareness through action-oriented activities.

Nature of Action: Community Based-Adaptation Strategy

5.2.3 Sea Level Rise (SLR) Vulnerability Assessment of Tourism Assets, Infrastructure and Settlements

5.2.3.1 Light Detection and Ranging (LiDAR)

Using Light Detection and Ranging (LiDAR) data; connecting with remote sensing experts in the region and internationally, this Action will involve being placed onto a satellite based platform with appropriate resolutions that would meet the needs and purposes of The Bahamas. In addition, the Action would involve flying specific shorelines to collect LiDAR data. Priority shorelines would be identified in coordination with stakeholders. Shorelines would be rated on criteria such as size, importance to tourism economy, population density, geology (i.e., sandy beach versus cliff profile), biodiversity, and ecology (i.e., shore and marine habitats and species). This approach would contribute to more accurate profiling for Comprehensive Disaster Management, the Biodiversity sector and insurance/actuarial assessments. Costs may be high and the process time-consuming, but these potential constraints should be investigated as the accuracy and use of LiDAR data for SLR assessments and storm surge impact predictions for a variety of sectors would be extremely advantageous. A LiDAR based study is recommended for the same areas where the GPS work has been completed in Eleuthera as part of the seed funding phase. This would enable triangulation of the data collected and also increase the robustness of the socioeconomic assessments conducted on infrastructure and settlements in those areas.

5.2.3.2 GPS Surveying

Using GPS Surveying; this Action recommends the importance of building on the demonstration project conducted in Eleuthera with the Bahamas Meteorological Service. This successful local and national capacity building, skills transfer and primary data gathering project should be expanded. The small-scale approach should be conducted in other study areas throughout The Bahamas. As different shore reaches are completed, local staff will be trained on an on-going basis, these local experts will then train others and conduct additional shore reaches that the institution believe are priority areas. Equipment could be purchased or hired and this process would be rolled out over every nation in the Caribbean Basin delivering effective capacity building and quality data upon which pragmatic decisions and assessments can be made.

5.3 *Water*

5.3.1 Water Assessment

Some work has been done in The Bahamas on water quantity and quality, though not on Eleuthera itself. This is an important area to develop further for all the islands in The Bahamas. The Action here is to determine changed availability via detailed scenarios from the modelling work conducted as part of the CARIBSAVE seed funding project. Scenarios should be developed for future demand based on population and economic growth projections and increased need for users especially those directly related to the tourism sector. Broad scale modelling should first be implemented to identify areas of interest and vulnerability for more detailed analysis. Secondary data and literature should be used for range of scales and local, national, regional and international experts including the University of Oxford Water Research Centre should be involved in the process and identification of specific strategies.

5.4 *Energy*

5.4.1 Implementation of the Mitigation Spiral

When considering energy use for business and destinations in Eleuthera, taking steps along the path of low carbon towards carbon neutrality is paramount. These steps are illustrated by the ‘Mitigation Spiral’ (Annex 2). To have the greatest impact, this action must be coupled with cost savings for business. Savings to businesses along with a sustained approach towards carbon neutrality and ‘greening’ the destination will encourage commitment by the individual business owners. The stages towards carbon neutrality are: measurement; reduce energy use; employ the use of renewable (having researched the technologies, including new developments); offset the remaining emissions (using recognised gold standard offset projects, in the region if possible); and then reassess the process. The ‘spiral’ continues through steps 1 – 5 until the business or destination reaches the point of carbon neutrality.

5.4.2 Links with Existing and Forthcoming Energy Projects in the Region

To assist in the implementation of the steps of the 'Mitigation Spiral' and to provide crucial awareness and commitment by both the private and the public sector links to projects associated with energy use and the tourism sector are vital. For example, **a)** The Bahamas has been identified by the CCCCC and the University of Oxford as a Pilot Study Site for the Inter-American Bank funded Carbon Neutral Project. The involvement of The Bahamas in this important project for the region will serve to lift the nation more quickly towards the goal of carbon neutrality; **b)** Links with the on-going Travel Foundation project working with Small, Medium and Micro Enterprises (SMMEs) to rationalise energy use in tourism accommodation providers should be established. A roll out of the initiative in Eleuthera and The Bahamas should be assessed; c) The Caribbean Hotel Energy Efficiency Action (CHENACT) project (currently at shortlist stage) will establish an excellent platform for hotels and accommodation providers throughout the region to both save money and increase the use of renewables in their businesses. The Bahamas should engage with the implementation agencies and the project team (once selected) and take steps to learn from the pilot processes being undertaken in Barbados when they commence in the next few weeks.

5.4.3 Climate Policy and Carbon Neutrality Research Needs

Introduction to research

It is widely acknowledged that the Caribbean accounts only for 0.2% of global emissions of CO_2, even though the region hosts a population of 40 million, corresponding to 0.6% of the world's population (Dulal *et al.,* 2009). However, in some countries, and in particular those that have developed their tourism systems, per capita emissions are exceeding levels that can be considered sustainable (Table 1). Countries like Aruba (21 t CO_2 per capita/year), Antigua and Barbuda (5 t CO_2 per capita/year), or The Bahamas (6 t CO_2 per capita/year) all have per capita emission levels that are close to or even exceed those in developed countries, and many exceed the global average of about 4.3 t CO_2 per capita per year (UNSD 2009). If the Caribbean's contribution to global emissions of CO_2 is currently still comparably low on a regional basis, i.e., 0.2% of global emissions, this is largely due to populous islands including Cuba and Haiti and their comparably low per capita emission levels. If all countries had emission levels such as The Bahamas, the region would considerably exceed its emission share to population ratio, i.e., contribute disproportionally to climate change.

This raises questions for the future, as there are global ambitions to reduce emissions of greenhouse gases, in particular addressing those countries emitting on above average per capita emission levels. More specifically, the IPCC recommends that global CO_2 emissions should be reduced by at least 50% by 2050 (IPCC, 2007c). This would be a minimum required to avoid global average temperature increases beyond 2°C by 2100, or what is generally seen as the maximum level of global warming to avoid "dangerous interference with the climate system" (e.g., Meinshausen *et al.,* 2008). Emission reductions are based on the principle of shared but differentiated responsibilities, which are negotiated during the so-called Conference of Parties meetings. Industrialized countries, or Annex I countries, are expected to contribute disproportionally higher to emission reductions, based on a per capita emission basis. This could mean for the Caribbean that in the future, emission reductions will be expected even from those countries exceeding average global per capita emission levels.

Method

Research is consequently needed to understand which sectors contribute to emissions of greenhouse gases, and how these could be reduced. Even though the statistical base for this needs to be developed, it seems clear that most of the emissions in the Caribbean are a result of fossil energy use, and in particular fuels (e.g., Dept. of Statistics of the Bahamas, 2009; Central Bureau of Statistics Aruba, 2009). A considerable share of fuel imports can again be linked to tourism, particularly in those islands being highly dependent on tourism (Gössling *et al.,* 2008). Given the economic importance of tourism for the Caribbean, the project would consequently lay particular focus on this sector, and an understanding of its emissions, analyzed by sector. The methodology for this will be based on Forsyth *et al.* (2008) and Gössling and Hall (2008).

In a second step, it will be investigated how greenhouse gas emissions will grow in the future, and how global climate policy will affect growth in these sectors. Strategies for mitigation will be developed. In the case of tourism, focus will be on options to make the sector carbon neutral (Simpson *et al.,* 2008; Gössling and Schumacher 2010). There is huge potential to yield considerable additional funds from tourists to realize such concepts and these need to be developed for the Caribbean as well. The methodology for this specific project will be based on Gössling (2009) and Gössling and Schumacher (2010).

5.5 *Agriculture*

5.5.1 Development of Agriculture

To reduce food miles (greenhouse gas emissions) created by the importation of food for the tourism industry and encourage alternative and complimentary industries to tourism. School children are encouraged to see the value of farming, on an island where a great proportion of fresh produce needed by the tourism industry is imported. Agriculture in St Lucia is in decline. A career in agriculture offers children secure future employment and also reduces food miles for the huge amount of fresh produce required by the tourism industry. The school will also earn an income by selling herbs to hotels, enabling it to fund extra resources, such as books.

Nature of Action: Community Based-Adaptation Strategy with potential Policy overtones due to requirement of land use and funding for equipment to support the development of the sector.

5.6 *Biodiversity*

This sector will be further examined and developed whilst undertaking the Country profile.

5.7 *Human Health*

This sector will be further examined and developed whilst undertaking the Country profile.

5.8 *Identification of those Most Vulnerable*

5.8.1 Vulnerabilities, Livelihoods, Gender and Climate Change

Introduction to research

Impacts of climate change will be differently distributed among different regions/destinations, generations, age classes, income groups, occupations and genders (IPCC, 2007a). In light of the estimated current rate of climate change related deaths of 300,000 per year, which is anticipated to increase to

500,000 by 2020 (Global Humanitarian Forum, 2009), it is of great importance to identify the most vulnerable groups in society in order to develop climate change adaptation strategies tailored to them. Adaptation will be particularly relevant in high-risk areas, including coastlines. Moreover, the most vulnerable groups are generally those with no financial resources, who are also working in or dependent on 'high risk' sectors, such as tourism, agriculture or forestry, and in particular when employed in low-paid staff positions (cf. Massiah 2006). Within these groups, yet another sub-division can be made between men and women, as women are particularly vulnerable to climate change (e.g., Massiah 2006; Dulal *et al.* 2009), while their role in generating adaptive capacity is disproportionally important (cf. Berkes *et al.,* 2000). It is increasingly recognized that vulnerabilities are closely interlinked with gender, and that women in many areas are particularly vulnerable. One example is the 1991 cyclone disaster in Bangladesh, where 90% of casualties were reportedly women (Aguilar, 2004).

Consequently, vulnerability research should have a strong gender focus, a view that is supported by the UN: "The United Nations is formally committed to gender mainstreaming in all policies and programmes, and that should include policy-making processes relating to climate change. Yet gender aspects are rarely addressed in climate-change policy, either at the national or at the international levels" (cited in Hemmati and Röhr, 2009: 19). Engendering climate change vulnerability research will also help to develop the emerging field of gender-related studies in climate change (see the 2009 special issue of Gender & Development on climate change).

While not ignoring a focus on the poor and most vulnerable more generally, research will specifically seek to understand the importance of five aspects in the context of climate change, vulnerability, resilience and generation of adaptive capacity, i.e., women's:
1) Knowledge and abilities
2) Professional positions, division of labour, income levels and savings behaviour
3) Resource use, access and control
4) Health, insurance & security
5) Participation in decision-making, including politics

Method

A project covering as many issues of central importance as this one needs to build on a complex research methodology, which will have to be developed in more detail when the project is approved. Another compounding problem is that only little research has been carried out on climate change and gender issues, and a range of new insights can be expected from this project.

The following section detail, without description, of the methods that will be used and which data needs to be collected.

Statistical data and other relevant information will be gathered through:

- Identification of relevant reports, including national and international reports, working papers, policy documents, books and articles
- Consultation and participation of women's groups and related networks in the destinations and nations
- Stakeholder engagement (different sectors identified by the CARIBSAVE Partnership; water, energy, biodiversity, agriculture, infrastructure, disaster management, health)
- Requests and consultation with Government Ministries (including the Ministry of Tourism and those departments related to CARIBSAVE selected sectors)
- Coordination with University of West Indies (UWI) Centre for Gender Affairs and Development
- Secondary data collection though desktop studies

Statistical Information such as;

- Women’s employment rate / ratio in the destination / nation
- Women’s employment rate / ratio in the tourism sector in the destination / nation
- Women’s employment rate / ratio in other related sectors in the destination / nation (as identified in CARIBSAVE project; water, energy, biodiversity, agriculture, infrastructure, disaster management)
- Women’s salary levels in comparison to men
- Savings by women
- Women’s access to credit (finance)
- Multiple income sources at household level and/or resource use systems (property rights, kinship or share systems)
- Division of labour in between men and women
- Health, insurance & security systems for women

Other Information such as:

- Government’s role in mainstreaming gender perspectives into national policies and action plans related to climate change
- Identification of gender sensitive strategies for responding to environmental and humanitarian challenges presented by climate change

1) Knowledge and abilities

Lack of knowledge on climate change as a vulnerability issue - for example: if you do not know about sea-level rise, you will not choose a location for your home or business that is safe in a storm surge situation. As women may often have considerable power in making household-related decisions, basic knowledge about climate change would count as an important precondition for adaptation.

=> **find out** through consultation and workshop about knowledge of climate change in population, and particularly among women; find out whether there are other areas where women are disadvantaged because of lack of skills.
=> **find out** in addition, the differentials between women’s and men’s vulnerabilities i.e., how different climate change impacts (e.g., flooding and droughts) would affect men and affect women.
=> **find out** how men’s and roles change and may complement each other when coping with climate change

2) Professional positions, division of labour, income levels and savings behaviour

Professional position - for example: women do household related work and have no access to a cash income. Or because of their positions in low-paid jobs in tourism, women may be the first to be dismissed from their job when tourist numbers decline. Or because they are lowest paid they have no option to put aside savings. BUT women may nevertheless in many households be those that actually put aside money (or other resources). So women may, through their savings/storage of food etc., build resilience in times of hardship. Women may also have different jobs to cope with risk.

=> **find out** about the share of women working for a cash income; which positions women typically occupy in tourism and other sectors; if they have multiple jobs; how much they typically earn, as well as their financial situation including savings. We may also try to find out whether there are social security systems for women.

3) Resource use, access and control

Role of women in use of natural resources, or access to resources - example: CC may affect in particular those ecosystems that are already degraded. Women might prevent destructive resource use practices, if they know about the consequences, or they may organize for this purpose if there are larger players (say the hotel industry building jetties through reefs etc.).

=> **find out** about the role of women in traditional resource use (and knowledge) systems, and their access to resources (land, water, etc.) Also the comparison between women and men's responsibilities for resources, i.e., issues referring to property rights.
=> **find out** about the role of women in food production.

4) Health, insurance & security
Women may be more vulnerable in disaster situations – example: when there is a disaster situation, such as for instance flooding, it may be women who are the least mobile, also taking care of the children.

=> **find out** about the health, insurance and security systems that are in place in case of risk, emergency or disaster.

5) Participation in decision-making, including politics
Participation in decision making – how are women organized, can they influence decisions with regard to CC? For instance, the growth paradigm in tourism may usually be a male concept?

=> **find out** about role of women in decision-making, and how their perspectives could influence adaptation and how women's roles in decision-making differs from men's

Additional questions that may serve as a non-exhaustive discussion guide to stimulate sharing of national/destinational level experiences, strategies and good practices in relation to gender and climate change.

- What steps are being taken / could be taken to **mainstream gender perspectives** into the climate change efforts at the destinational, national and regional levels – including in policies, strategies, action plans and programmes? What good practice examples can be provided?
- What steps are being taken / could be taken to **reduce the vulnerability of women** and to reduce the negative impacts of climate change, particularly in relation to their critical roles in rural areas in provision of water, food and energy? What good practice examples can be provided?
- What steps are being taken / could be taken to **increase the participation of women** in decision-making on climate change at different levels? What good practice examples can be provided?
- What are the **major contributions of women as agents of change** in mitigation and adaptation to climate change at local levels? What good practice examples exist, and how can these be made more visible and more effectively utilized?
- What are the critical issues for women in relation to **technology and finances** in addressing climate change at national and local levels?
- What are the **major achievements and gaps and challenges** in ensuring adequate attention to gender perspectives in climate change efforts, for example in relation to specific issues/contexts, such as natural disasters, i.e., floods and drought

5.9 *Comprehensive (Natural) Disaster Management*

Table 5.8-1: National disaster risk management agencies

Country	Name of disaster agency	Date established	Mandate	Portfolio Ministry	Existence of legislative framework	Gender-sensitive policy
Belize	National Emergency Management Organization (NEMO)	1999	"the preservation of life and property"	Ministry of Transport, Public Utilities, Communications	Disaster Preparedness and Response Act, Cap 245 of the Laws of Belize, Revised Edition 2000-2003.	No
Dominica	Office of Disaster Management (ODM)	1983	"protection and safety of the people and assets of the country, the sustainability of our social and economic progress, and our future survival as an independent *nation*". Policy and Mission Statement	ODM reports to the National Emergency Planning Organization (NEPO), in the Ministry of Public Utilities	Reports indicate that a legislative framework is currently being drafted.	No
Dominican Republic	National Commission for Emergencies	1966	Responsible for disaster risk management	Reports to the Office of the President	Extensive Legislative Framework (see below)	No
Guyana	Civil Defence Commission (CDC)	1982	Responsible for disaster risk management	Civilian agency in Office of the President	Operates under general legislation regulating the operations of the Office of the President.	No
Jamaica	Office of Disaster Preparedness and Emergency Management (ODPEM)	1980	Responsible for disaster risk management	Ministry of Local Government and Environment	Operates under Section 15 of the Disaster Preparedness and Emergency Management Act.	No

Source: UNDP (2008)

5.9.1 Mainstreaming Climate Change Impacts on Tourism into Comprehensive Disaster Management (CDM) using Evidence-based Planning

The Bahamas has been involved as one of the Pilot Sites for the IDB/DFID funded and CDERA implemented Regional Disaster Risk Management for Sustainable Tourism in the Caribbean Project. The work conducted by the CARIBSAVE seed-funding project in The Bahamas, including the climate modelling, vulnerability profile and adaptive capacity profile should be used to mainstream climate change factors into the tourism strategy and plan of action for CDM. This Action will be most effective once at least two further destinations have been assessed through the CARIBSAVE climate change analysis process (see Annex 3). This mainstreaming Action will not only enhance The Bahamas tourism sector's protection and resilience to natural disasters by taking full and evidence-based account of climate change impacts, but also provide a template for this work in other countries across the Caribbean Basin. Once the climate change factor is taken into account in the sector, tourism is well placed to take a lead in CDM as it crosses institutional and organizational scales, as well as interacting across sectors; as such it has the capacity for effective actions and providing an arterial network for dissemination. With its growing appreciation and understanding of the impacts and challenges presented by climate change it can offer leadership in initiating CDM processes that involve stakeholders, build on and learn from existing good practice, raise awareness of the challenges and of potential solutions, and develop sector-relevant disaster managements plans, systems and structures to take the region and individual nations forward to a more resilient future

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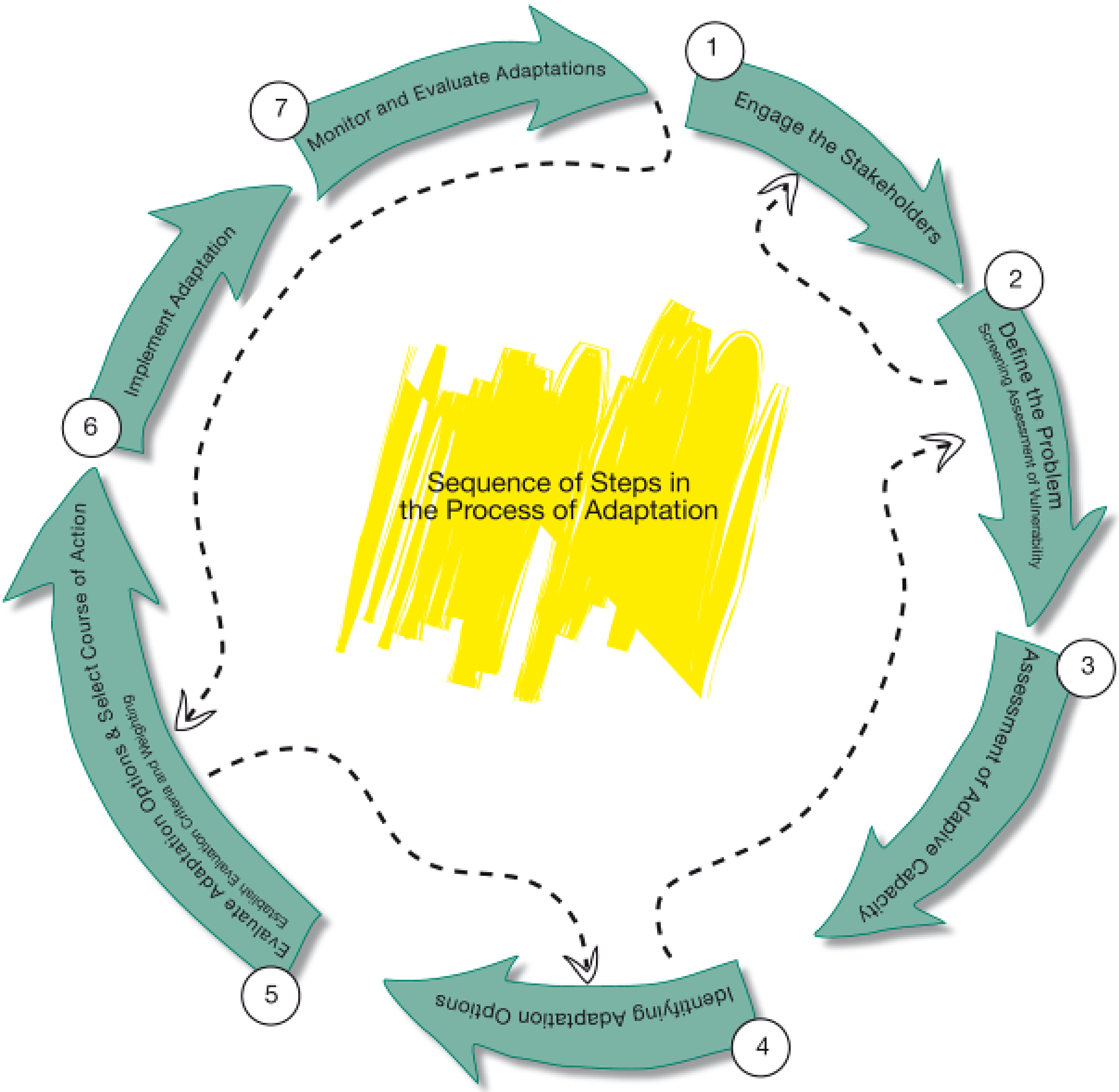
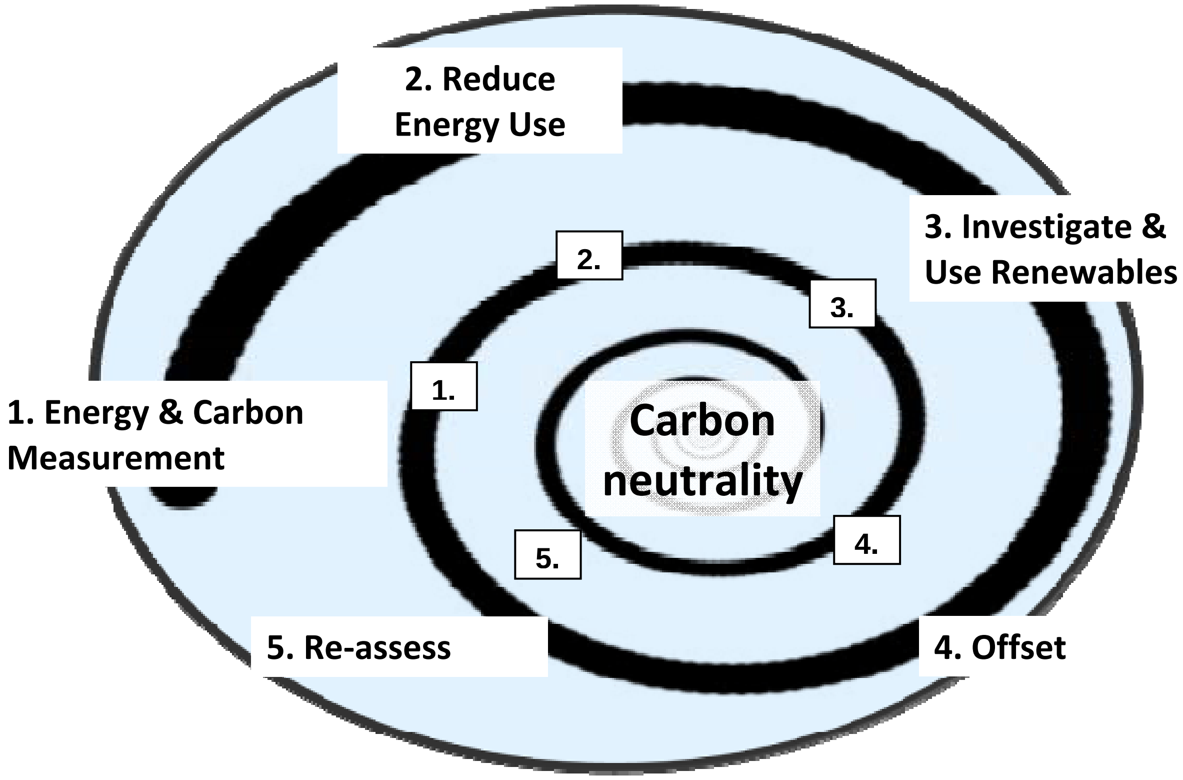
8. ANNEX

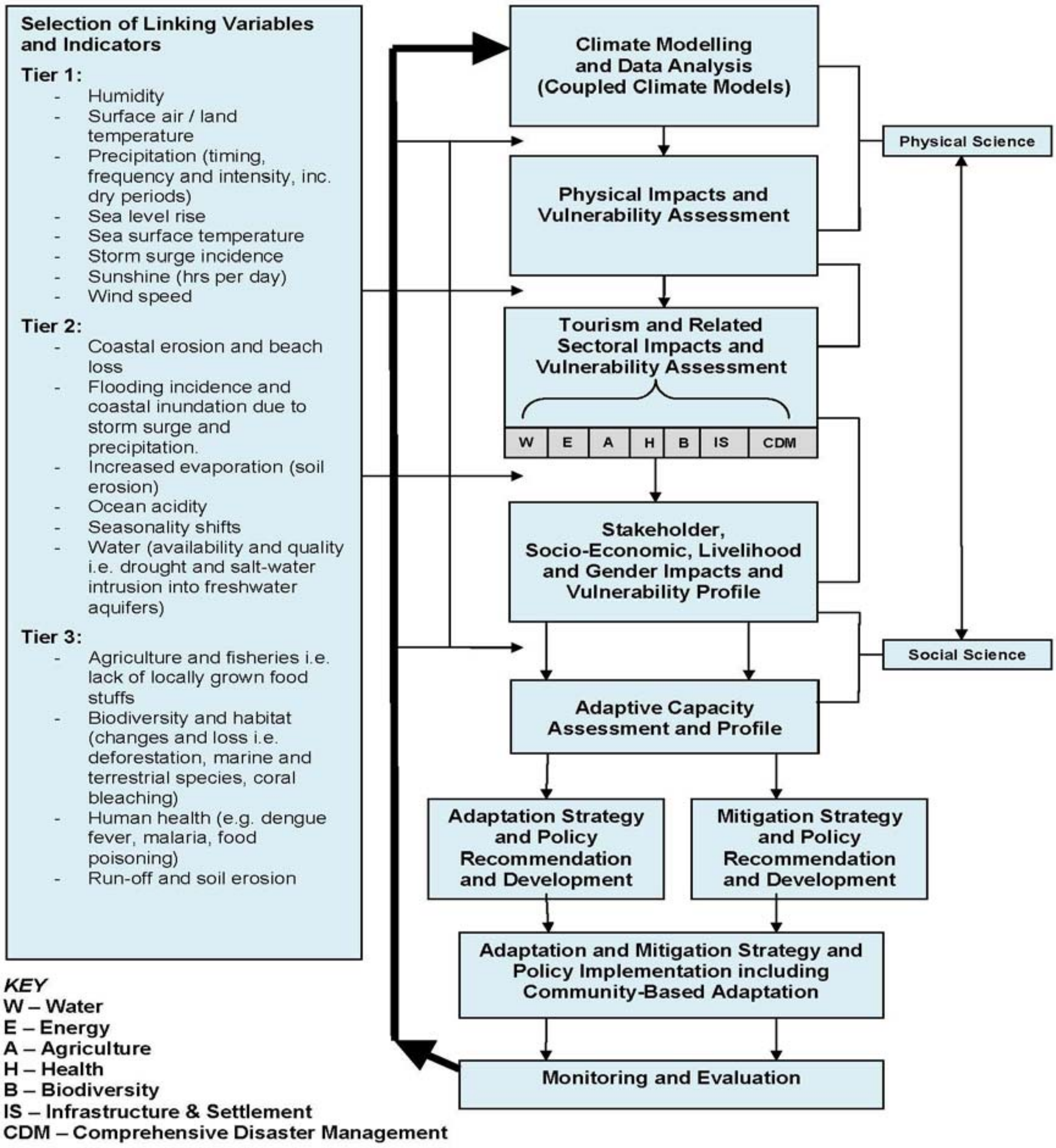
Annex 1: Adaptation Cycle



Annex 2: Mitigation Spiral



Annex 3: Flow Chart of Methodology



Flow Chart Summary: CARIBSAVE Climate Change Analysis, Strategy Development and Implementation (Component example)