Assessing climate change and its likely impact on selected UK Overseas Territories: Inception Report

Steven Wade, Adam Leonard-Williams and Kate Salmon

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Report Summary

This is the Inception Report for the DFID "Climate Change in Overseas Territories" project. Its purpose is two-fold. Firstly, to provide a short overview of available climate information, climate change impacts and the key planning decisions sensitive to climate change. Secondly, to describe our approach to the project and work required to complete a comprehensive report by February 2016.

SECTION 1

Introduction

Project background

The UK Government is ultimately responsible for the security, economic wellbeing and sustainability of 14 UK Overseas Territories (OTs) (Appendix A). Successive White Papers have committed HMG to meet the “reasonable assistance needs” of the OTs as a “first call” on the aid budget where financial self-sufficiency is not possible. This situation prevails in St Helena (including Tristan da Cuhna) in the South Atlantic; Montserrat in the Eastern Caribbean and the Pitcairn Islands in the Western Pacific. The underlying strategy is focused on three objectives: economic growth and development – leading to self-sufficiency; the sound management of public finances; and stronger technical support drawing on the full range of government departments.

Climate change is receiving increased international attention, as demonstrated by its inclusion as a specific Sustainable Development Goal (SDG). Climate change is also prioritized by the Department for International Development (DFID) as a Strategic Development Priority. The Secretary of State for International Development has emphasised the importance of integrating climate and development investments across the DFID portfolio. By 2020, DFID should be delivering a fully integrated approach to sustainable, climate resilient economic development in line with the SDGs.

DFID’s Oversees Territories Department (OTD) is responsible for meeting HMG’s commitment to the OTs and delivering its strategic objectives. Interventions include financial support (budget aid), the provision of technical assistance, and capital funding for essential infrastructure. The latter typically includes roads, water, waste and power services, communications, public buildings (for example, health facilities) and harbour works (piers, jetties and breakwaters). An airport on St Helena, supported by DFID, is also nearing completion.

To ensure that reasonable assistance needs are met whilst achieving value for money, the impact of climate change has to be considered. This is particularly important given the vulnerability of relatively small, isolated OTs to climate change, and the relatively high value of DFID’s investment in infrastructure, noting that the life of the assets being created is measured in decades, not years. For example, sea defences on Montserrat have to be designed taking into account the risk associated with hurricanes; water sources on St Helena have to be identified taking into account possible changes in rainfall patterns. This is entirely consistent with DFID’s broader policy relating to infrastructure, which highlights the need to enhance the resilience of the built environment and reduce vulnerability to extreme weather events and climate change.

The "Climate Change in Overseas Territories" project

This project aims to provide up to date information on how climate variability and climate change impact on selected OTs to support the Bilateral Aid Review (BAR) and DFID operational plans. The geographical focus is the South Atlantic (limited to St Helena and Tristan da Cunha); the Caribbean (focusing on Anguilla, Bermuda, British Virgin Islands, Cayman Islands, Montserrat, Turks and Caicos Islands), the Western Pacific (Pitcairn Islands) and the Indian Ocean (British Indian Ocean Territory – which includes the island of Diego Garcia). Most of these islands are located in the tropics but the most remote island, Tristan da Cunha, is much further south in the South Atlantic (Figure 1, Appendix A for a more detailed map).

The potential impacts of climate change in the Caribbean region have been studied in some detail[1] but the other territories have not. Previous reviews have highlighted the vulnerability of OTs due to their reliance on a fragile natural resource base and the ecosystem services it provides, including coastal protection, fisheries and water supply. In a 2001 review, tourism, fisheries, water supply and migration were highlighted as 'critical choke points' for the island's decision makers (Sear et al., 2001). A stakeholder survey as part of the same project revealed that disaster risks (tropical storms, floods, droughts) related to the current climate were the primary concern. Longer term climate change risks are now higher on the agenda, particularly in the context of key decisions related to investment in infrastructure and future economic sustainability of some territories.

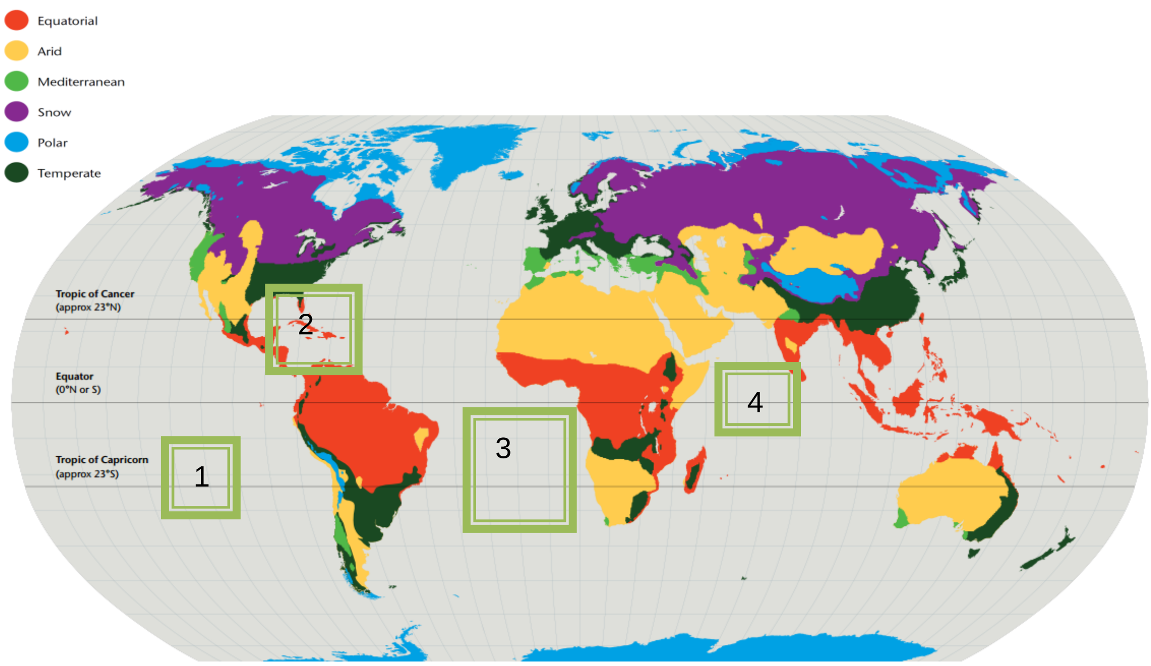


Figure 1 Koppen climate classification and locations of selected British Overseas Territories: [1] Pitcairn; [2] Cayman, Burmuda, Turks and Caicos, British Virgin Islands, Anguilla and Montserrat; [3] St. Helena and Tristan de Cunha and [4] British Indian Ocean Territory

Source: http://www.metoffice.gov.uk/media/pdf/4/d/Weather_and_climate_guide.pdf

[1] A number of centres have been established to work on climate change impacts and adaptation in the Caribbean. For examples the 5Cs is a recognised focal point: http://www.caribbeanclimate.bz/

Assessment approach

From a climate perspective the OTs of interest are located in four distinct ocean basins with local climate strongly linked to ocean conditions and influences such as the El Niño (see the next section). We will consider climate information for these four distinct domains using available data from observations, Global Climate Models and, where available, Regional Climate Models. We will consider the baseline of current conditions, the 2050s and longer term changes.

The evidence collected and analysed for this study will include:

- A literature review on global climate change and regional changes starting with the Intergovernmental Panel of Climate Change (IPCC) Fifth Assessment Report and including further peer-reviewed and grey literature on climate impacts, adaptation and vulnerability of small islands.
- Collation of climate and hazard data sets from observations and sources available to the UK Met Office such as ERA-Interim Re-Analysis data, Global Climate Models and global marine data sets. The Met Office has previously developed more detailed downscaled climate change scenarios for the Caribbean Region.
- Collection of information on any critical thresholds that would affect the sustainability, economic well-being or essential services on the islands, such as existing flood defence levels, or threshold sea surface temperatures that would alter coastal ecosystems.
- Expert opinion from local engineers and environmental scientists, other Government experts including FCO, DFID and Met Office, primarily through review of our draft report and telephone consultation on any key issues.

SECTION 2

Weather and climate in Overseas Territories

This section presents a basic synopsis of the weather and climate in the selected Overseas Territories, together with an overview of the main environment hazards.

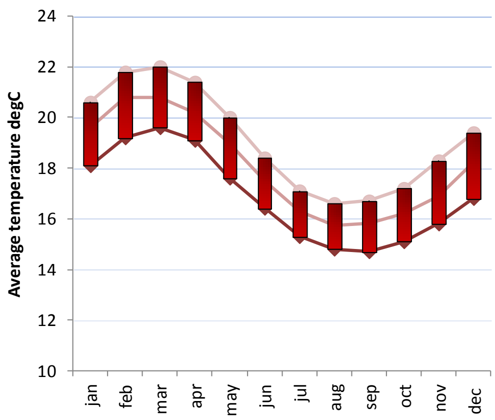
Main drivers

Christensen et al. (2013) provides a useful summary of the dominant climate drivers for various regions:

- The Caribbean region is affected by several climatic phenomena, predominantly the Inter-Tropical Convergence Zone (ITCZ), El Niño Southern Oscillation (ENSO) and tropical cyclones.
- St. Helena experiences a sub-tropical marine climate influenced by the South Atlantic Anticycle (SAA), which drives the dominant South East trade winds.
- Tristan de Cuhna, further to the south has a more temperate maritime climate and is equally affected by the SAA.
- The British Indian Ocean Territory, in the central Indian Ocean, has a tropical oceanic climate and is affected by both the Indian Ocean Dipole and ENSO.
- Pitcairn in the pacific islands region has a tropical wet climate and is also heavily influenced by ENSO and the ITCZ.

Baseline climatology

Baseline climate information is available from observations on some islands as well as from global data sets. The World Meteorological Organisation (WMO) Voluntary Cooperation Programme has a long history with some of the OTs including Gough Island, Pitcairn and St. Helena and therefore some data are available and archived by global climate centres. St. Helena has a long climate record with some observations back to the 19th century (Feistal *et al*., 2003). Annual rainfall totals are highly variable and at 504 mm (382mm-678mm), very low, making this the driest of the OTs (Figure 2).



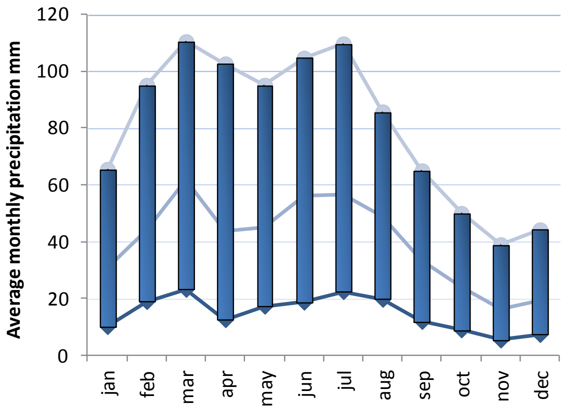


Figure 2. Long term median, 5th and 95th percentile mean monthly temperature and precipitation on St Helena (1893-2015) (Source: Feistal et al., 2003)

Box 1: ENSO

El Niño and La Niña are opposite phases of what is known as the El Niño-Southern Oscillation (ENSO) cycle. The ENSO cycle is a scientific term that describes the fluctuations in temperature between the ocean and atmosphere in the east-central Equatorial Pacific (approximately between the International Date Line and 120 degrees West).

La Niña is sometimes referred to as the cold phase of ENSO and El Niño as the warm phase of ENSO. These deviations from normal surface temperatures can have large-scale impacts not only on ocean processes, but also on global weather and climate.

El Niño and La Niña episodes typically last nine to 12 months, but some prolonged events may last for years. While their frequency can be quite irregular, El Niño and La Niña events occur on average every two to seven years. Typically, El Niño occurs more frequently than La Niña.

El Niño
The term El Niño refers to the large-scale ocean-atmosphere climate interaction linked to a periodic warming in sea surface temperatures across the central and east-central Equatorial Pacific.

Typical El Niño conditions influence weather patterns, ocean conditions and marine fisheries across large portions of the globe for an extended period of time. The Eastern Caribbean – Haiti, Dominican Republic, Puerto Rico, US Virgin Islands, St. Maarten, and Barbados – is very likely to be extremely warm and likely to be dry in the developing phase of El Niño conditions. Following the peak of El Niño, the North Western Caribbean – Cuba, Bahamas and Jamaica – is likely to be extremely wet. This has previously caused flooding events which i can increase the risk of Dengue Fever. El Niño is also known to suppress hurricane activity in the Atlantic Basin. The equatorial Central and East Pacific (Pitcairn) is very likely to experience warm and wet conditions during the peak of El Niño and extremely wet conditions are very likely in the Central Indian Ocean (BIOT).

La Niña
La Niña episodes represent periods of below-average sea surface temperatures across the east-central Equatorial Pacific. Global climate La Niña impacts tend to be opposite those of El Niño impacts. In the tropics, ocean temperature variations in La Niña also tend to be opposite those of El Niño.

Source: http://oceanservice.noaa.gov/facts/ninonina.html
Also see: http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/gpc-outlooks/el-nino-la-nina/ENSO-impacts and http://dx.doi.org/10.12774/eod_cr.august2015.hironsletal

Table 1 presents basic climatology statistics for wind speed and significant wave height. Wind and wave statistics are derived from in Met Office global wave model hindcast which runs from 2001-2015, and are representative of the offshore conditions. Examples of climate information available are included in Appendix B.

Table 1 Typical wind and wave statistics

Island	Median, 5^{th} and 9^{th} %ile Wind Speeds (mph). Typical wind direction (from).	Median, 5^{th} and 9^{th} %ile offshore Significant Wave Height (m). Typical wave direction (from)
Turks & Caicos	15 [6 – 23] NE – SE	1.5 [0.8 – 2.8] E-NE
BVI	13 [6 – 21] NE – SE	1.5 [0.9 – 2.7] E-NE
Anguilla	13 [6 – 21] NE – SE	1.5 [0.9 – 2.7] E-NE
Cayman	14 [6 – 22] SE	1.2 [0.5 – 2.2] SE
Montserrat	15 [7 – 21] NE-SE	1.6[0.9 – 2.7] E-NE
Bermuda	14 [4 – 28] SW-NW (winter), SW (summer)	1.7 [0.8 – 4.0] Variable, NW winter.
St.Helena	16 [9 -22] SE	2.0 [1.3 – 3.2] SE-SW
Tristan De Cuhna	18 [6 -33] SW – NW	3.0 [1.6 - 5.5] SW
British Indian Ocean Territory	13 [4 -22] SE (Jun-Nov), NW (Dec-May).	2.0 [1.2 – 3.3] SE-S

In the draft final report we will collate available information on the baseline climate from available sources (Appendix B). For any long data sets, trends will be reviewed and a number of indicators, such as frequency of heavy rainfall, will be calculated.

Hazards

Tropical Storms and Cyclones

Tropical storms and cyclones form the dominant climatic hazard for the Caribbean region. The strong winds cause significant damage through storm surges and associated waves, flooding and fresh water contamination. There is significant year-on-year and decadal variability in the number of tropical storms and hurricanes, which is related to ENSO conditions. Since 1970, in the Atlantic basin, the number of storms of category 3 and above has varied between 0 and 7 per year, and the number of named tropical storms has varied between 2 and 15 per year (Figure).

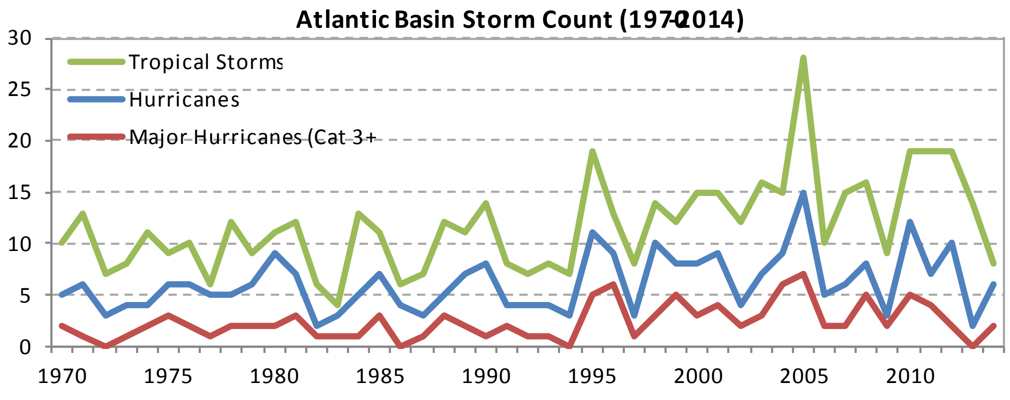


Figure 3 Number of tropical storms in Atlantic basin 1970-2014

Tropical storms pose a small hazard for the British Indian Ocean Territory, where 40 tropical storms have passed within 200 miles since 1970. Only one category 4 or 5 storm has come close to islands in this time because the Archipelago is close to the storm genesis region, so few reach maturity in the vicinity of the islands.

It should be noted that although direct risk from tropical storms can be small, swell waves from very distant storms (>1000km) can have significant impact on some island nations, as experienced by the Maldives and other Indian ocean island groups in 2007 (Nurse et al, 2014).

Coastal erosion and flooding

Coastal erosion is an issue to varying degrees across the Caribbean Island territories, and is the result of a number of factors. Storm waves from hurricanes cause significant and lasting damage and can result in wholesale changes to coastal morphology. Winter swells from the Atlantic affect the exposed North facing coasts of some islands. (Anguilla, BVI, Turks and Caicos). Coastal development, deforestation, destruction of mangroves and coral reefs and sand extraction all have had significant impacts on coastal erosion on all islands. Sea level rise is likely to exacerbate the issue and accelerate the process in some cases, especially the lower-lying islands and those with large mangrove areas, such as Cayman and Turks and Caicos (Section 3).

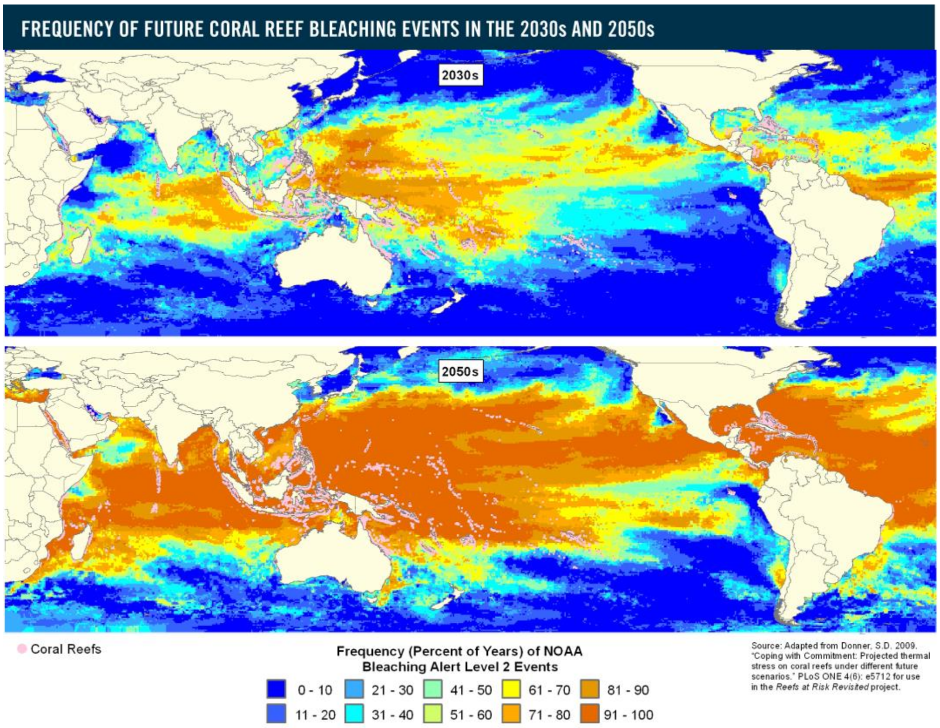
Coral Reef Bleaching

Coral reefs provide the biodiversity that the economy and livelihoods of the OT economies rely on, but they are also highly vulnerable to climate change. Increasing sea surface temperatures can cause coral bleaching which reduces reproduction and growth rates, making corals more susceptible to mortality (Barker et al. 2008) (see Box 2 on the impacts of bleaching). Mass coral bleaching events occur when sea surface temperatures are ≥ 2°C higher than average (Donner, 2009). Events such as these have already occurred in 1998 when a severe bleaching event affected 70-90% of corals in the British Indian Ocean Territory (Sear et al. 2001), and again in 2010 in parts of the Southern Caribbean (Alemu and Clement, 2014). Year 2015 is set to be one of the largest mass coral bleaching events yet due to the strong El Niño causing abnormally high sea surface temperatures (Witze, 2015).

On the British Virgin Islands, 90% of corals are already impacted by various anthropogenic pressures, which make them vulnerable to future bleaching (Virgin Islands Draft Climate Change Issues Paper, 2009). The frequency of future mass coral bleaching will depend on increases in regional sea surface temperature (SST) which are expected to rise in the tropics by 0.6-0.8°C by 2030-2039 (1980-2000 baseline) using Global Climate Model predictions forced with 5 different scenarios (Donner, 2009). This could mean that under business-as-usual scenarios, more than half of the world's coral reefs could be exposed to frequent thermal stress by 2030. High resolution ocean models have projected the average year for the onset of annual severe bleaching is 2040–2043 for all projections in Caribbean reefs under the RCP 8.5 business-as-usual scenario (van Hooidonk et al. 2015) (Figure 4).

Figure 4. The percentage of years each decade where a NOAA Bleaching Alert Level 2 (i.e. severe thermal stress) is predicted to occur, based on the IPCC A1B business-as-usual emissions scenario.

Predictions are adjusted to account for historical temperature variability but not for resistance or resilience factors. Figure taken from http://www.wri.org/resource/frequency-future-coral-reef-bleaching-events-2030s-and-2050s adapted from Donner, (2009).



Global sea surface temperatures (SSTs) are on average 1°C higher now than 140 years ago and are expected to increase up to another 0.5-0.75°C under RCP 4.5, and 0.75-1.0°C, since 1986-2005, under RCP 8.5 during the 2016-2035 period (Villarini and Vecchi, 2012). It is therefore vital to rigorously record and quantify these bleaching events in order to characterise the scale to which corals and their associated ecosystems are threatened by increasing SSTs.

River and flash floods

Heavy rainfall associated with tropical storms is an issue for many OTs including those in the Caribbean, Pitcairn and BIOT. Although small islands do not have large rivers, heavy rainfall can cause flash flooding and exceed the capacity of any existing drainage systems.

Soil erosion and landslides

Caribbean OTs with steeper terrain (e.g. British Virgin Islands) can suffer from soil erosion and landslides during heavy rainfall events. On St Helena, heavy rainfall has contributed to rock falls.

Droughts

Although many OTs have high annual rainfall, their small catchment areas, general lack of water storage and saline intrusion and incursion mean that hydrological and water resources drought can be an important issue. This is particularly the case where water resources are limited, such as in St Helena and Anguilla. .

Multi-hazards

Montserrat has been identified as susceptible to 'multi-hazard' events including tropical storms combining with heavy rainfall, which could trigger a volcanic dome collapse and make evacuation by sea difficult (Gray, 2007).

In the draft final report we will collate available information on natural hazards with a focus on the location of critical infrastructure, such as coastal defences, ports, airports, energy and water supplies.

Box 2. Impact of coral bleaching on fisheries and communities

Fisheries and seafood farms are critically dependent on the health and physical protection of coral reef, seagrass and mangrove ecosystems and are thus also adversely affected by rising sea surface temperatures and intense storm surges exacerbated by warmer temperatures (Knutson et al. 2010). This could be detrimental to several communities on different OTs. For example in Anguilla reef fish make up over half of the landed catch (53%) (Wynne, 2013) and in the Turks and Caicos islands lobster and conch farming is worth around $3 million each year (Homer and Shim, 2000). Likewise, the lobster fishery in Tristan da Cunha accounts for 90% of the island's revenue (Ovenstone proposal review, 2007) and the estimated total economic value for Bermuda's reef ecosystem ranges between US $488 million-$1.1 billion/year accounting for tourism ($405 million), coastal protection ($266 million), recreational/cultural ($37 million), fisheries ($5 million), amenity ($6.8 million) and biodiversity research ($2.3 million) (Sarkis et al. 2013). Based on this, the coral reef ecosystems constitute 12% of Bermuda's GDP (Sarkis et al. 2013).

In order to minimise the impact of longer term climate change on reef communities and associated industries that rely on them, it is crucial to:

- Regularly record and quantify the health of coral reefs
- Reduce pollution, sedimentation and overfishing
- Protect areas where natural environmental conditions improve resistance and resilience
- Develop rapid adaptive management responses when bleaching events occur.
- Undertake further research into how ENSO and El Nino are related to coral bleaching events

There are a number of useful sources of information on coral reefs and biodiversity in OTs. Examples of these are included in Appendix B.

SECTION 3

Climate change projections

This section presents an overview of some of the key climate change projections that are likely to have a significant impact on the Overseas Territories. The most up-to-date peer reviewed results from the IPCC Fifth Assessment Report have been used, as well as other sources of relevant information. Projections for emission scenarios RCP2.6 (a mitigation scenario) and RCP8.5 (a business as usual scenario) are shown to provide an illustration of the possible range of changes. Where possible the analysis period has focused on the middle of the century 2035-2065 and comparisons are made to the reference period 1961-1990. In some cases projections from other periods are used due to data availability.

Temperature and Precipitation

Table 2 presents estimates of changes in temperature and precipitation. These are results from the CMIP5 global climate models that contributed to the IPCC AR5 analysis and have been extracted using the KNMI Climate Explorer data tool. The table shows the mean relative change in near surface temperature and relative change in precipitation for the period 2035-2065, relative to the 1961-1990 average. These results are ensemble means, i.e. the average results from a large number of global climate models. There is uncertainty around these estimates, which is shown in the plots in Appendix B.

Table 2 Summary of mean changes in temperature and precipitation from AR5 RCP2.6 and RCP8.5, for the period 2035-2065, relative to 1961-1990.

Island	Relative change in near surface air temperature by 2035-2065 (°C, mean of model ensemble)		Relative change in precipitation by 2035-2065 (%, mean of model ensemble)	
	RCP2.6	RCP8.5	RCP2.6	RCP8.5
Turks & Caicos BVI Anguilla Cayman Montserrat	1.2	1.8	0%	-6%
Bermuda	1.2	1.8	2%	1%
St.Helena	1.0	1.6	-4%	-7%
Tristan De Cuhna	0.9	1.5	1%	5%
ArchipelagoBritish Indian Ocean Territory	1.1	1.8	3%	3%
Pitcairn	0.7	1.1	-5%	-9%

The mid-century changes in temperature are significant but the mean changes in annual rainfall are small and within the range of natural variability. The seasonal changes in rainfall may be more important along with any changes in the frequency or magnitude of heavy rainfall or drought conditions. A number of downscaling studies have been undertaken in the Caribbean (Taylor et al., 2007), Indian Ocean (Maunsell Australia pty, 2009) and the Western Tropical Pacific (Australian Bureau of Meteorolgy and CSIRO, 2011).

In the draft final report annual and seasonal changes in key climate variables will be presented using available information for the 2050s and 2080s. Regional Climate Model outputs will be investigated to see if higher resolution data provides different *estimates of future change. For small islands these data should provide much improved projections due to the higher resolution and better representation of local atmospheric processes.*

Sea Surface Temperature

Sea surface temperatures are expected to increase at similar rates but there is less easily accessible information on rates of rise for different emissions scenarios. The relevant data will be collated for the draft report.

Tropical Cyclones

While climate change projections clearly indicate an intensification of the hydrological cycle with increases in global average precipitation there is still limited consensus or clear projections for Tropical Cyclones. Knutson et al (2010) and Christensen et al (2013) state that large amplitude fluctuations in the frequency and intensity of tropical cyclones greatly complicate both the detection of long-term trends and their attribution to rising levels of atmospheric greenhouse gases. Trend detection is further impeded by substantial limitations in the availability and quality of global historical records of tropical cyclones. However, results from modelling studies do show that:

- It is likely that global frequency of tropical storms will either decrease or remain unchanged.
- There is low confidence in projected changes in individual basins, such as the Atlantic or South West Indian basin.
- Some increase in mean maximum wind speed is likely, but not necessarily in all basins.
- Frequency of the most intense, high impact storms will more likely than not increase in some basins.
- Rainfall rates likely to increase, in order of 20% within 100km of tropical cyclone centre
- Low confidence in projected changes in genesis-location, tracks, duration and areas of impact. Existing projections do not show dramatic large-scale changes in these features.

Sea Level Rise

Estimates of global sea level rise for RCP2.6 and RCP8.5, for the reference period 2081 to 2100 are presented below in Table 3. The values presented are the median and likely range of sea level rise (Church et al., 2013).

Table 3 Estimates of global sea level rise 2081-2100 (median and 5-95%ile)

RCP2.6	RCP8.5
0.40m [0.26m–0.55m]	0.63m [0.45 – 0.82m]

Whilst these global estimates illustrate the possible end of century mean sea level rise, It is very likely that in the 21st century and beyond, sea level change will have a strong regional pattern, with some places experiencing significant deviations of local and regional sea level change from the global mean change (Church et al., 2013). There is a low probability that greater melting of ice sheets could lead to substantially higher rates of sea level rise of several metres. For this reason, planning in London where floods would have catastrophic damages, has considered a “H++ scenario” of around 2m of sea level rise by 2100.

To address this, further analysis will be undertaken using Met Office in-house data analysis tools to determine the range sea level rise estimates for each island location for the period

2035-2065 and beyond, for scenarios RCP2.6 and RCP8.5. The issue of whether to consider higher rates of sea level rise will be discussed with DFID.

SECTION 4

What are the implications for infrastructure, services and disaster risk reduction?

The Tyndall Centre report by Sear et al. (2001) provides a good overview of likely climate change impacts and the sectors that are most at risk. In general, for the vast majority of small islands nations their is a critical balance to be met between preserving and managing existing marine and coastal ecosystems, ensuring sustainable development and accounting for the numerous impacts of climate change.

Both Sear et al (2001) and Nurse et al (2014) breakdown the risks and impacts into four categories: climate change hazard, impacts on ecosystem and natural resources, impacts on livelihoods and impacts on settlements and infrastructure. Using these four headings and sourcing from Sear et al (2001) and Nurse et al (2014), we have listed the main climate risks and associated impacts for the overseas territories, as shown in Figure .

Figure 5 Overview of the dominant climate change hazards and associated impacts for Overseas Territories

Climate Change Hazard

- Changes in Temperatures
- Changes in Precipitation
- Sea Level Rise
- Changes in ocean temp
- Ocean acidification
- Changes in storminess

Environmental Impact

- Drought
- Limited water resources
- Salination of water and soil
- Increased flooding
- Coastal erosion
- Degradation coral reefs and mangroves
- Decrease in fish stocks
- Increased storm damage

Livelihood Impact:

- Losses of crops and agriculture
- Losses of fisheries and aquaculture
- Reduction in tourism (beach and coastal degradation)
- Decrease in health
- Increased migration

Infrastructure Impact:

- Under-designed coastal structures
- Reduction in harbour access
- Increased storm damage to buildings
- Inundation of coastal assets
- Inadequate drainage systems

Socio-economic background

The vulnerability of each island and its capacity to manage disasters and adapt to climate change depends on its socio-economic status, the balance of the economy in climate sensitive sectors and its overall economic wellbeing. Many of the Caribbean islands have experienced rapid economic growth in high end tourism, real estate and financial services. These may suffer damage to infrastructure due to tropical cyclones and a loss of tourist revenue but are generally well versed in disaster risk management. Montserrat is the exception and highly dependent on financial aid from the UK Government. Background information on selected islands is summarised in Table 4.

Table 4 Background information on selected OTs (based on 2007 National Audit Office report)

	Population	Land area km^2	Receipts $ m USD	Expenditure $ m USD	GDP per head £ thousands
Bermuda	63571	53	814	721	43
	Low Vulnerability. Very high GDP, although some economically disadvantaged communities. Mainly financial services and tourism. Tourism could be directly or indirectly impacted by tropical storms and longer term climate change.				
Turks and Caicos Islands	30602	430	150	143	9
	Medium Vulnerability. Main sectors are tourism and real estate. Some rapid growth based on property development. A lower GDP and reliance on tourism, which could be impacted by future climate change.				
British Virgin Islands	27000	153	233	203	21
	Low Vulnerability Mainly niche financial services. At risk from tropical cyclones but ranked as low because disaster management agency has a high capacity for dealing with natural disasters. Climate change risks will require similarly good management.				
Anguilla	13638	102	127	109	5
	Medium Vulnerability. High end tourism, which could be affected by climate change. A low GDP and reliance on tourism.				
Montserrat	4785	102	34	83	4
	High Vulnerability. Continued dependency on UK. Volcano still active and at risk of multiple hazards, with some logistical difficulties in effective evacuation.				
St Helena (inc. Tristan and Ascension)	5326	122	29	28	3
	High Vulnerability. Continued dependency on UK. Mainly fisheries and tourism. Narrow economic base that may benefit from increased tourism. Significant infrastructure development ongoing to promote sustainable economic growth that needs to be resilient to future climate change.				
Pitcairn	45	47	n/a	n/a	2
	High Vulnerability. Receiving DFID budgetary aid with a very low population and low income.				
BIOT	4000 (military personnel)	60	n/a	n/a	n/a
	Not currently applicable. No civilian infrastructure or economy in place.				

Source: Population and economic statistics from the National Audit Office, 2007.

Factors that make island economies vulnerable to climate variability and change include:

- Reliance on development assistance and/or tourism
- Reliance on one export and exports as % of GDP
- Import-dependency to meet domestic needs
- Insurance costs
- Accessibility
- Limited access to land resources, due to small physical size
- Low adaptive capacity, constrained by human and financial resources

The draft final report will collate more up to date socio-economic information but the focus will be on selected infrastructure, economic outputs or services and the ability of each island to manage tropical cyclones, floods and droughts.

What are the key decisions that need to be made?

UK Government strategy for the OTs focuses on economic growth and development, ultimately leading to self-sufficiency for those islands dependent on UK support. This typically involves maintaining or enhancing important ecosystem services, the development of tourism and associated infrastructure for including transport, energy and water supply. The long term sustainability of remote islands will affect decisions related to both resettlement of populations or relocation of inhabitants to other locations.

Therefore key decisions that need to be made vary from top level decisions on security and settlement policy to engineering and environmental management decisions on building climate resilience into new capital infrastructure projects and operations (Table 5).

Table 5. Examples of policy decisions for OTs and the relevance of climate change

Type of decision	Relevance of climate change	Comments
Resettlement	Resettlement of low lying coastal atolls is likely to be high risk and high cost. Sea level rise will increase extreme sea levels and rates of saline incursion/intrusion. Water resources are limited in some islands and may be reduced further under drier conditions (Table 2). Resettlement may increase pollution and illegal fishing in marine reserves.	More information is needed on the ground level and profile of BIOT's atolls to compare with sea level rise estimates. Climate change will influence costs, benefits and risks of any (re)settlement policies.
Marine conservation	Higher sea surface temperatures and increase in frequency of coral bleaching events. Climate change is likely to impact on fisheries and may result in increases or decreases in fish populations.	Sufficient financial provision required to maintain monitoring programmes, environmental protection and research on marine ecosystem surfaces. Diversification of economic sectors if risks to fisheries are high.
Disaster preparedness	Changes in the frequency or magnitude of heavy rainfall and tropical cyclones. Changes in water availability due to drought.	Need to ensure that sufficient capacity is in place for disaster risk management including the ability to provide external assistance or evacuate during extreme tropical cyclones.
Infrastructure resilience	As above. Climate impacts on extreme sea levels and heavy rainfall events.	Ensure adequate freeboard/climate change allowances are considered in the scheduling and design of infrastructure.

Health and social services	Impacts of climate change on disease vectors and vulnerability of children and elderly population in relation to tropical cyclones and floods.	Ensure that basic services are provided and plans are in place to deal with emergencies.
Security	Changes in the frequency of tropical cyclones or extreme sea levels impact operations at military ports or airports.	

The link between key decisions and climate change will be explored in more detail with DFID and other UK Government stakeholders.

SECTION 5

What are the gaps in our knowledge and how to fill them?

Climate change

The previous report by the Tyndall Centre (Sears et al. 2001) contained details of the perceived knowledge gap at that time. A number of these gaps will be addressed in the main report. These are:

1. Determine if it is possible to upgrade climate projections from global model data to regional model data
2. Investigate developments in research linking climate change to ENSO.
3. Improvements in the understanding of the link between climate change and tropical cyclones
4. Improvements in the understanding of patterns of changing rainfall

Linking climate variability and change to key sectors

It would be ideal to establish a closer link between historic climate variability and the output of key sectors, for example fisheries or tourist visitor numbers. However this requires both local climate information and economic data, which is unlikely to be achievable during the timescales of this project.

Understanding critical thresholds

The risks related to climate change depend on whether certain critical thresholds are exceeded, for example whether future extreme sea levels are higher than existing coastal defences or whether sea temperature are high enough to cause coral bleaching. We will collect some data on known critical thresholds to compare with more detailed climate projections. For example, data on the elevations above mean sea level of existing airports, access roads and other key infrastructure can be compared to extreme sea level estimates including climate change.

How to make decisions on islands given uncertainty in future change

In this inception note we have presented some ensemble mean changes in climate. In the draft report we will consider the wider range of possible future changes and consider how this may affect decision making with one or more examples.

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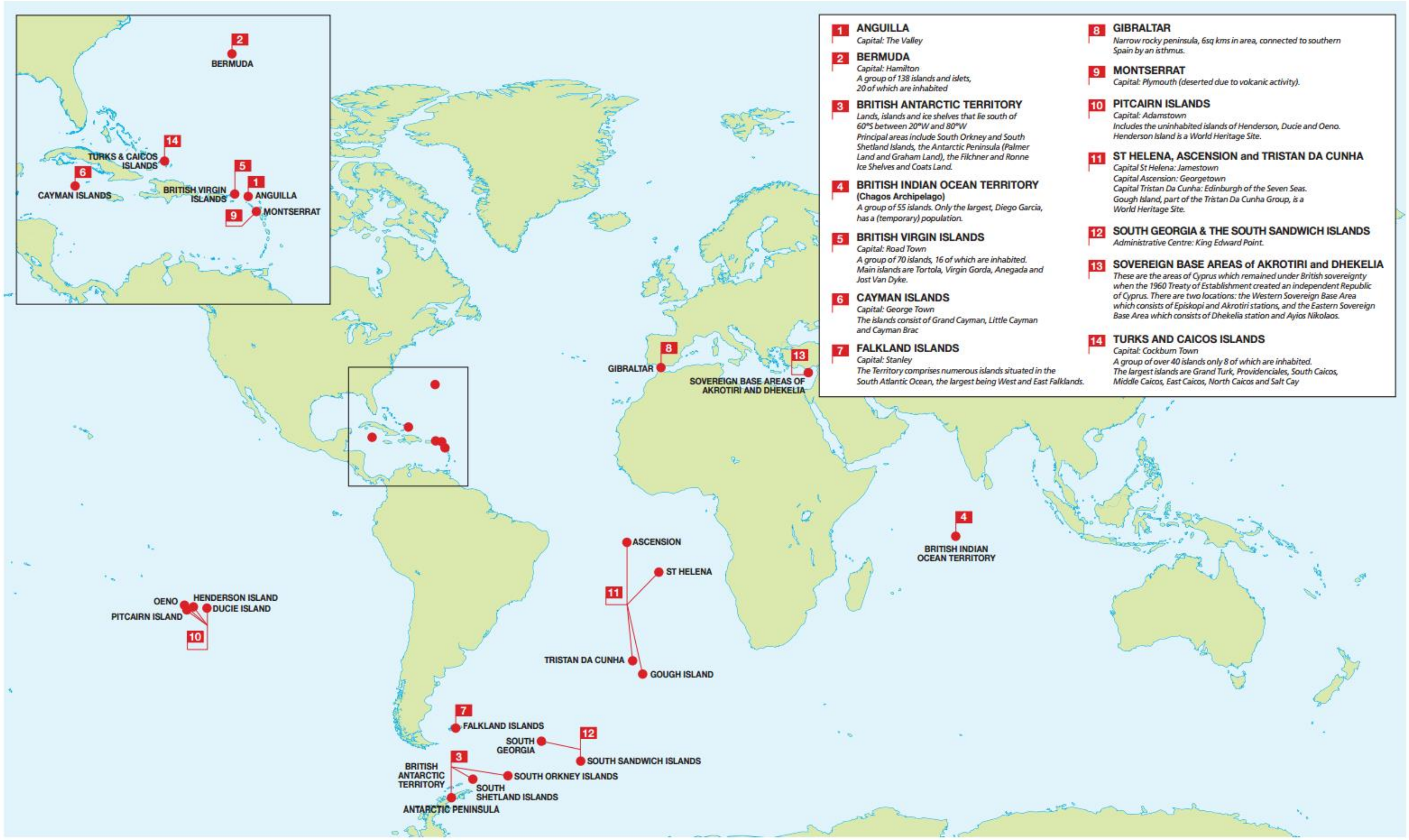
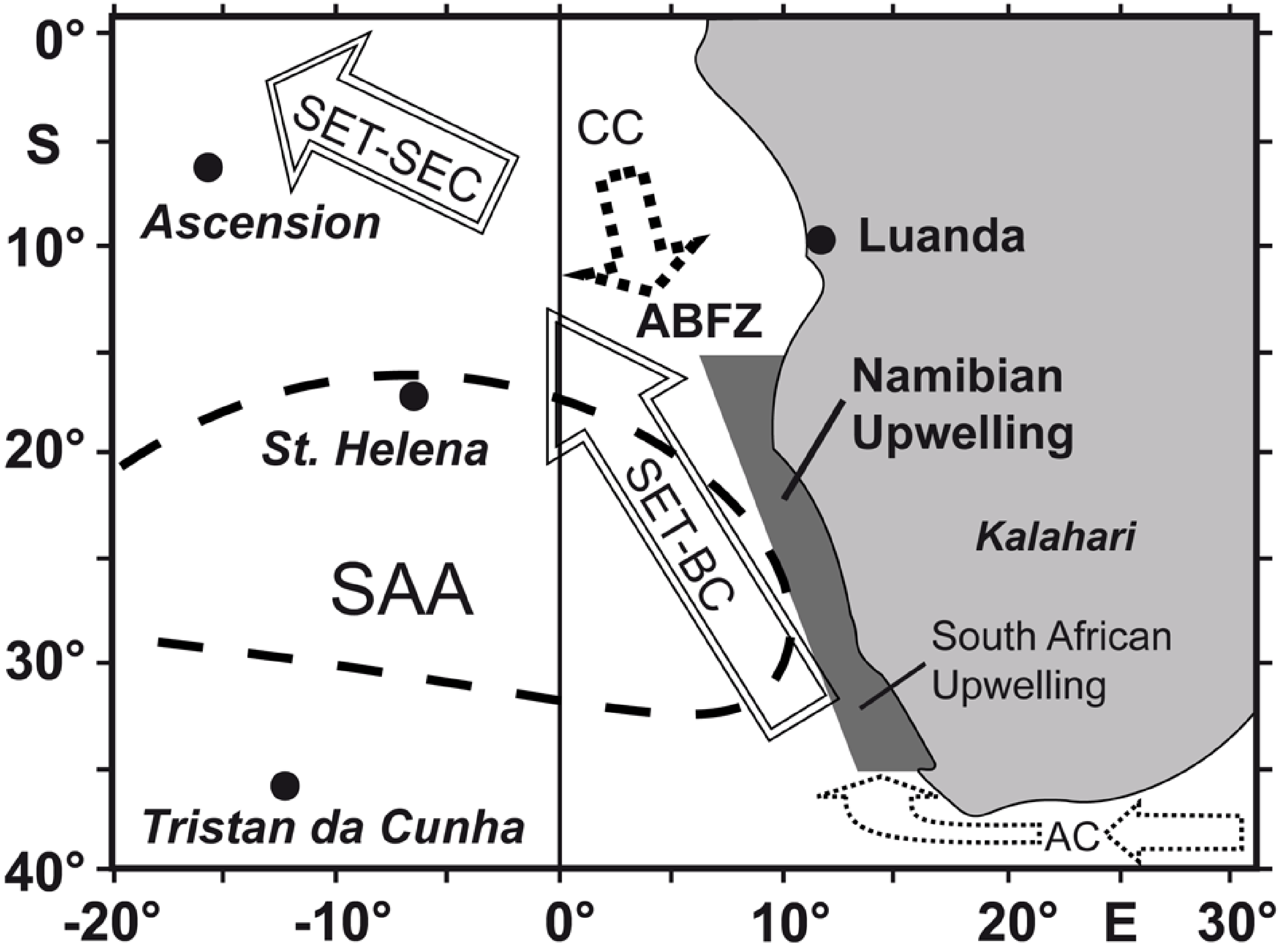
Appendices

Appendix A Maps

Location of the UKs 14 Overseas Territories



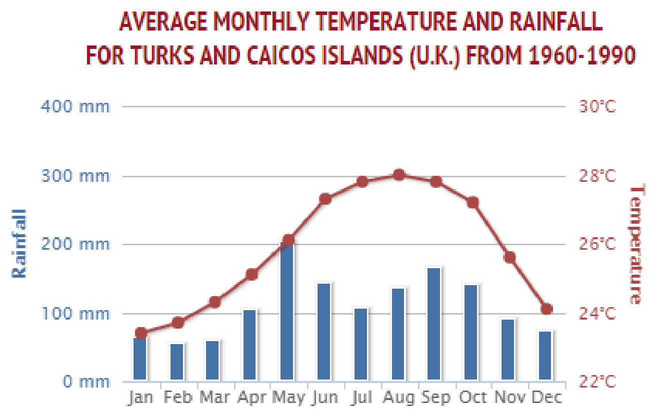
The South Atlantic Anticycle

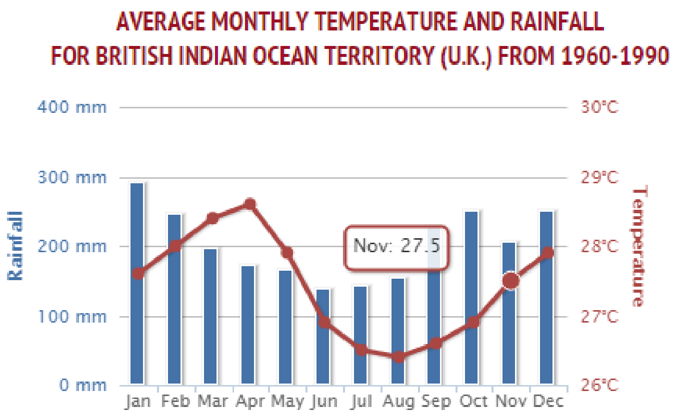


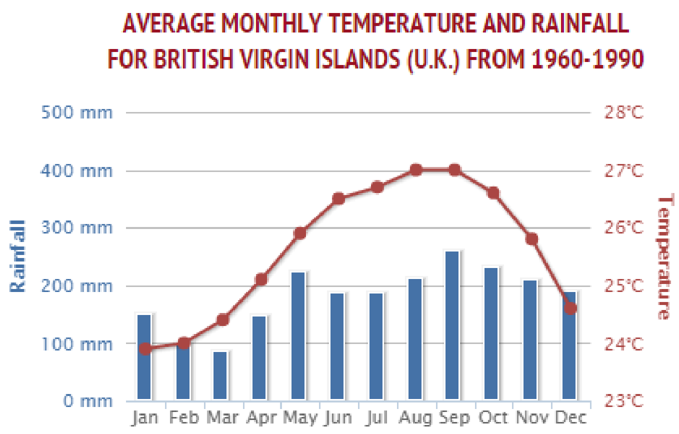
Source: http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00202.1

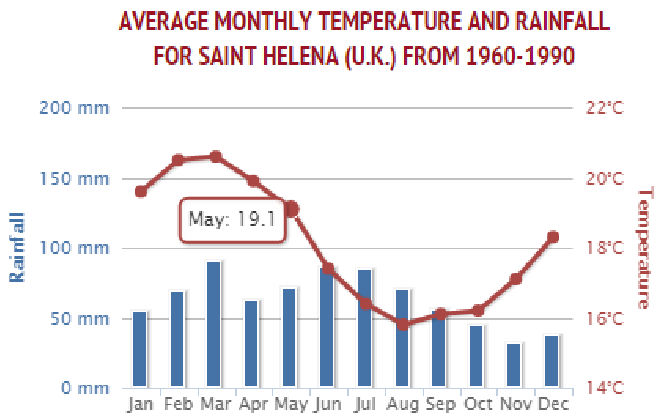
Appendix B Climate information

Average climate information from the World Bank portal



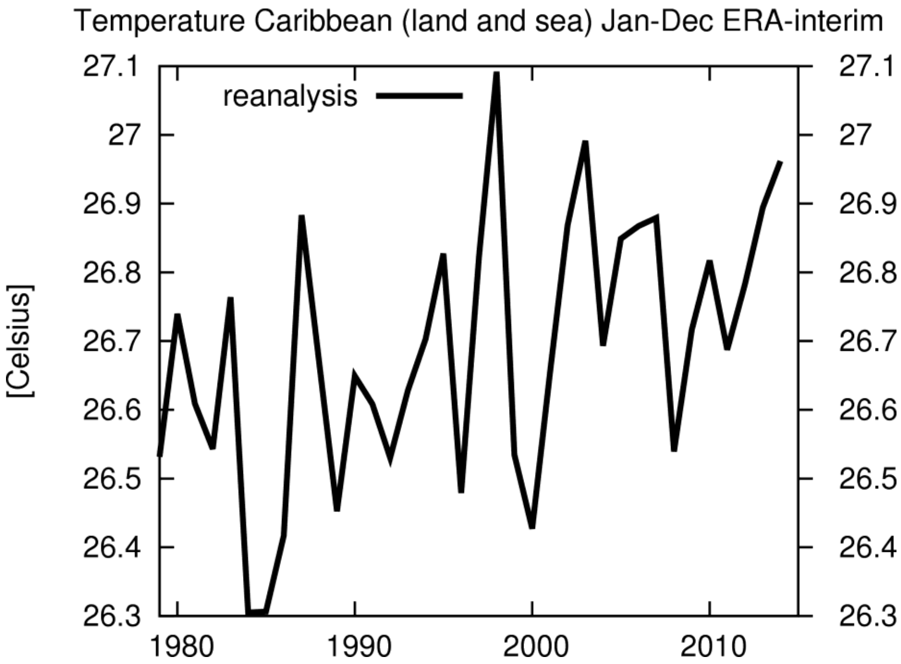


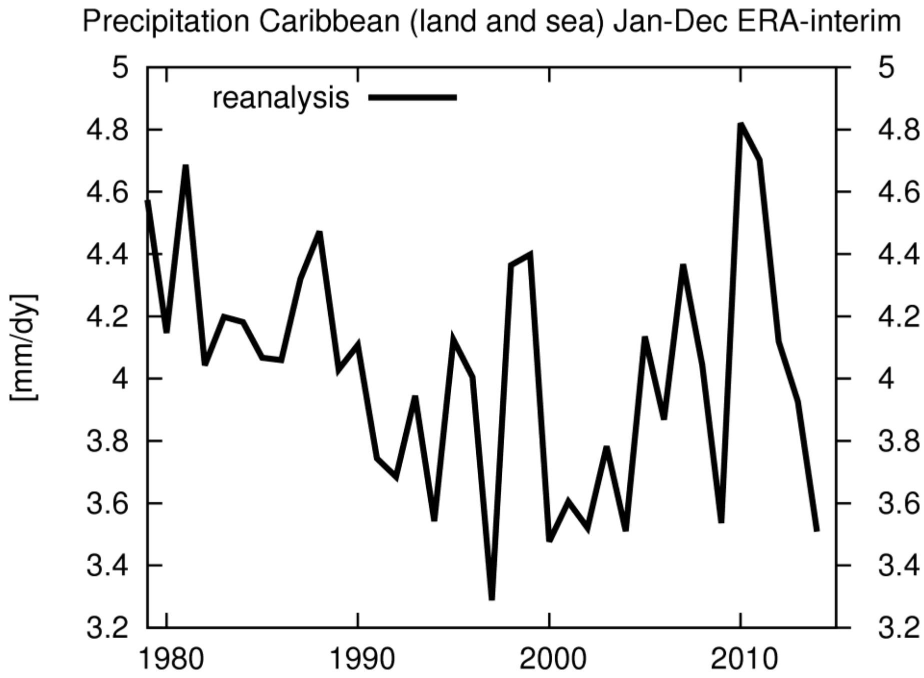




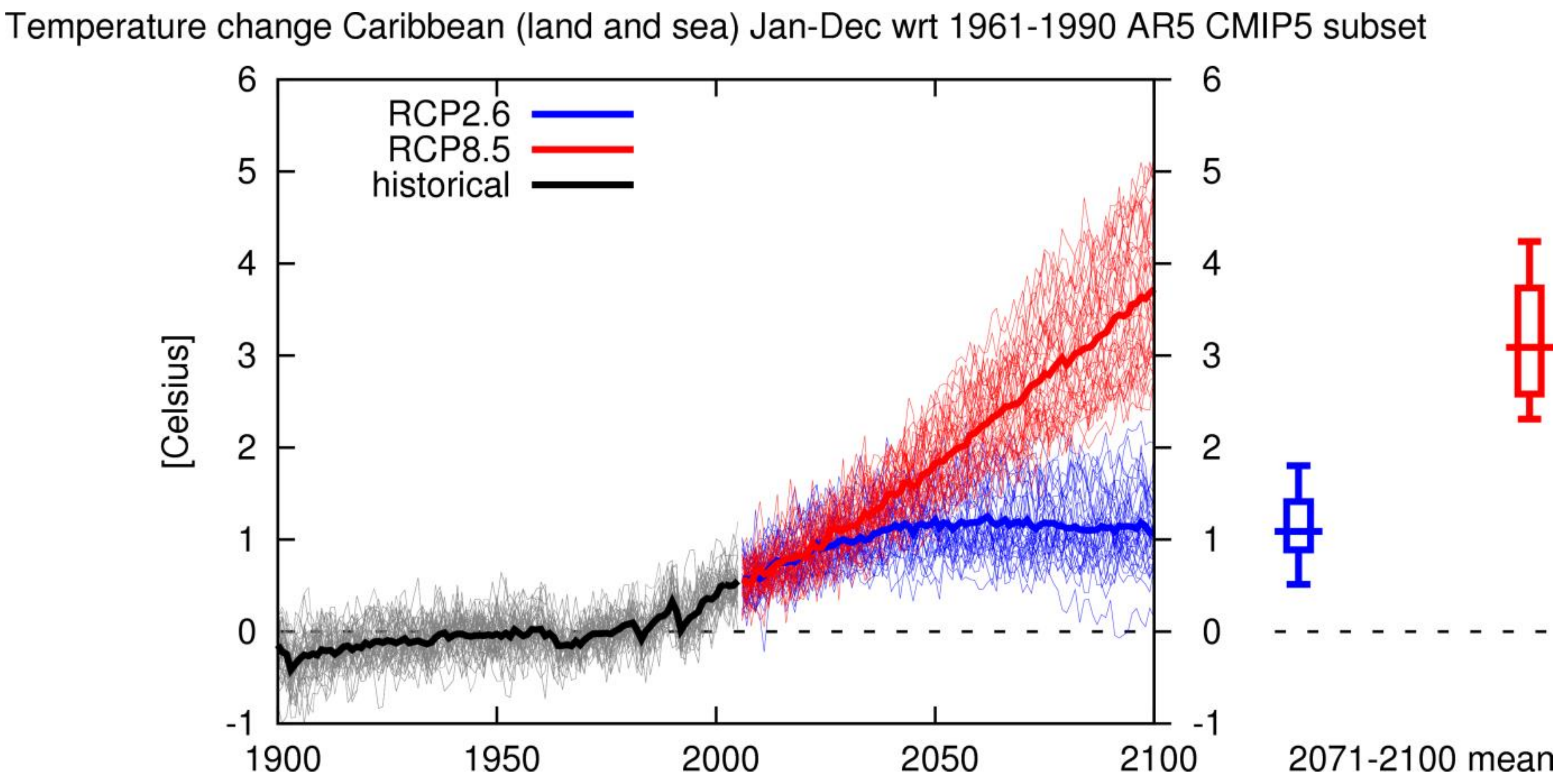
The dataset was produced by the Climatic Research Unit (CRU) of University of East Anglia (UEA).

Example of climate information from reanalysis data and Global Climate Models

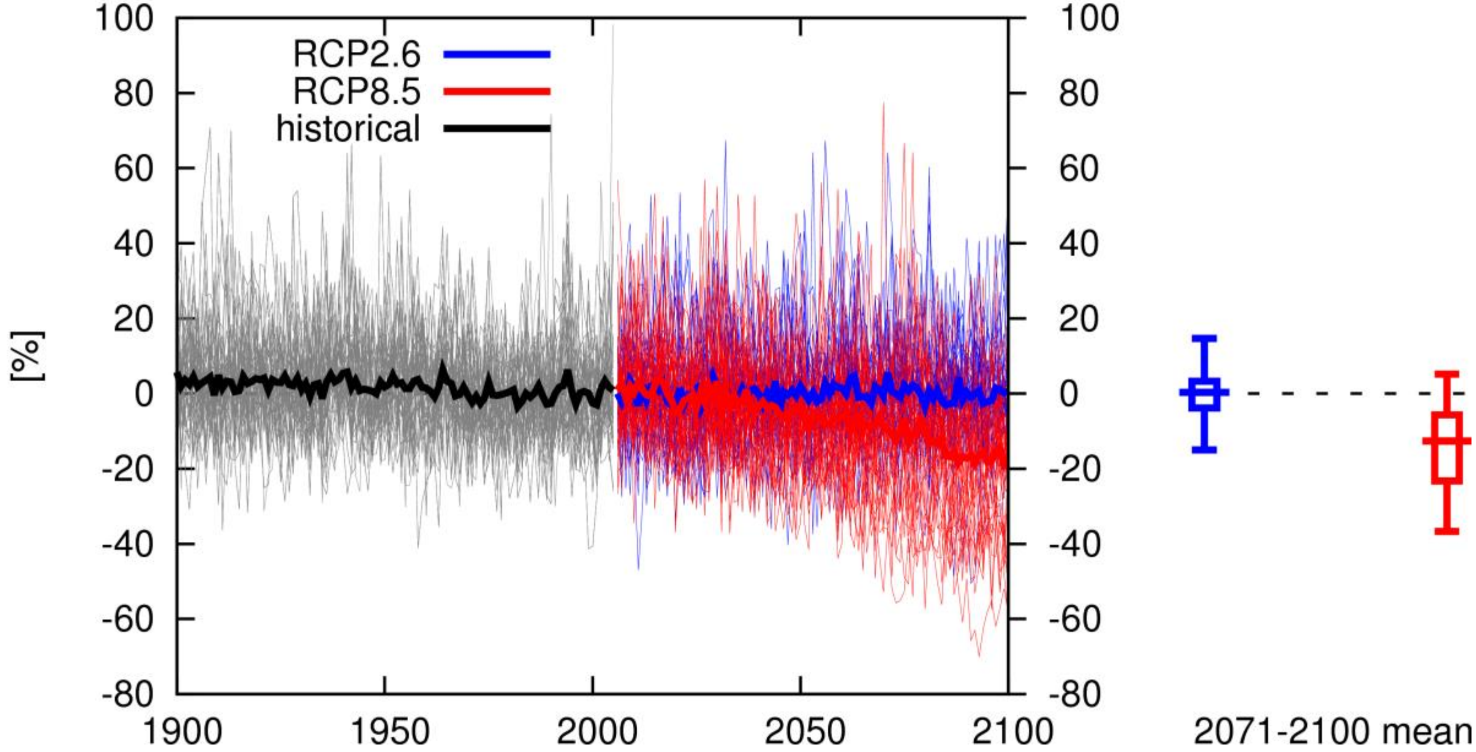




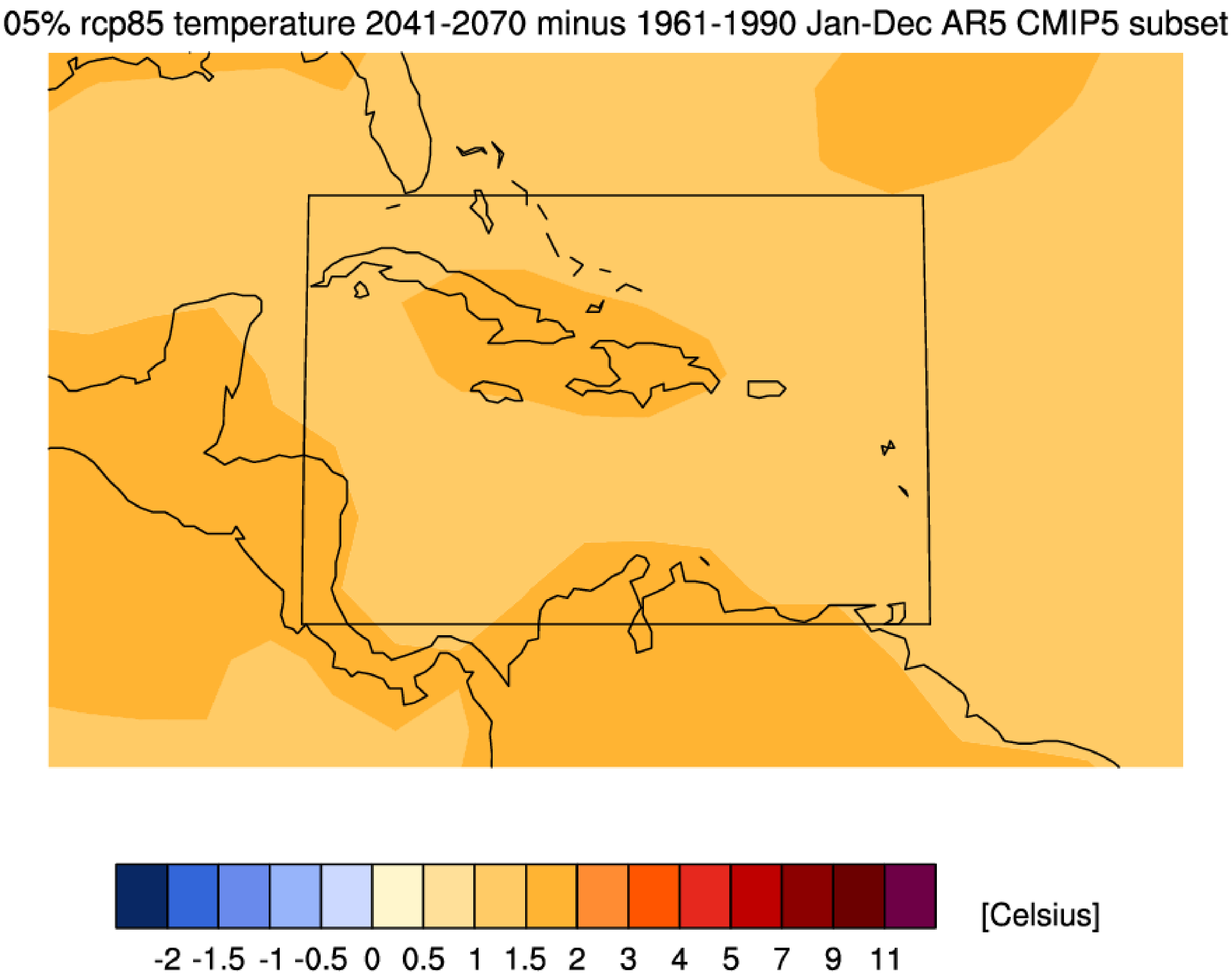
Global Climate Model data for the Caribbean

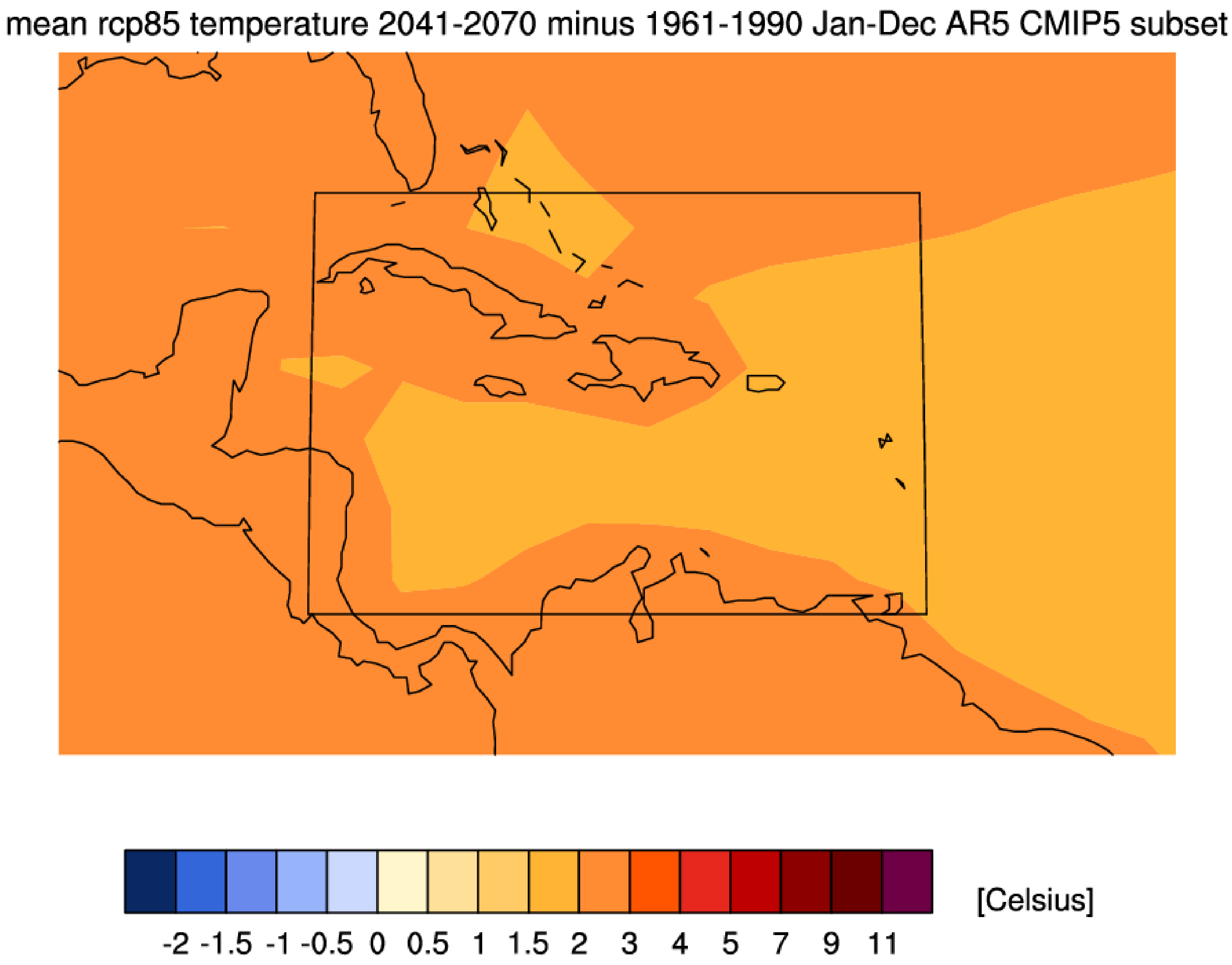


Relative Precipitation change Caribbean (land and sea) Jan-Dec wrt 1961-1990 AR5 CMIP5 subset

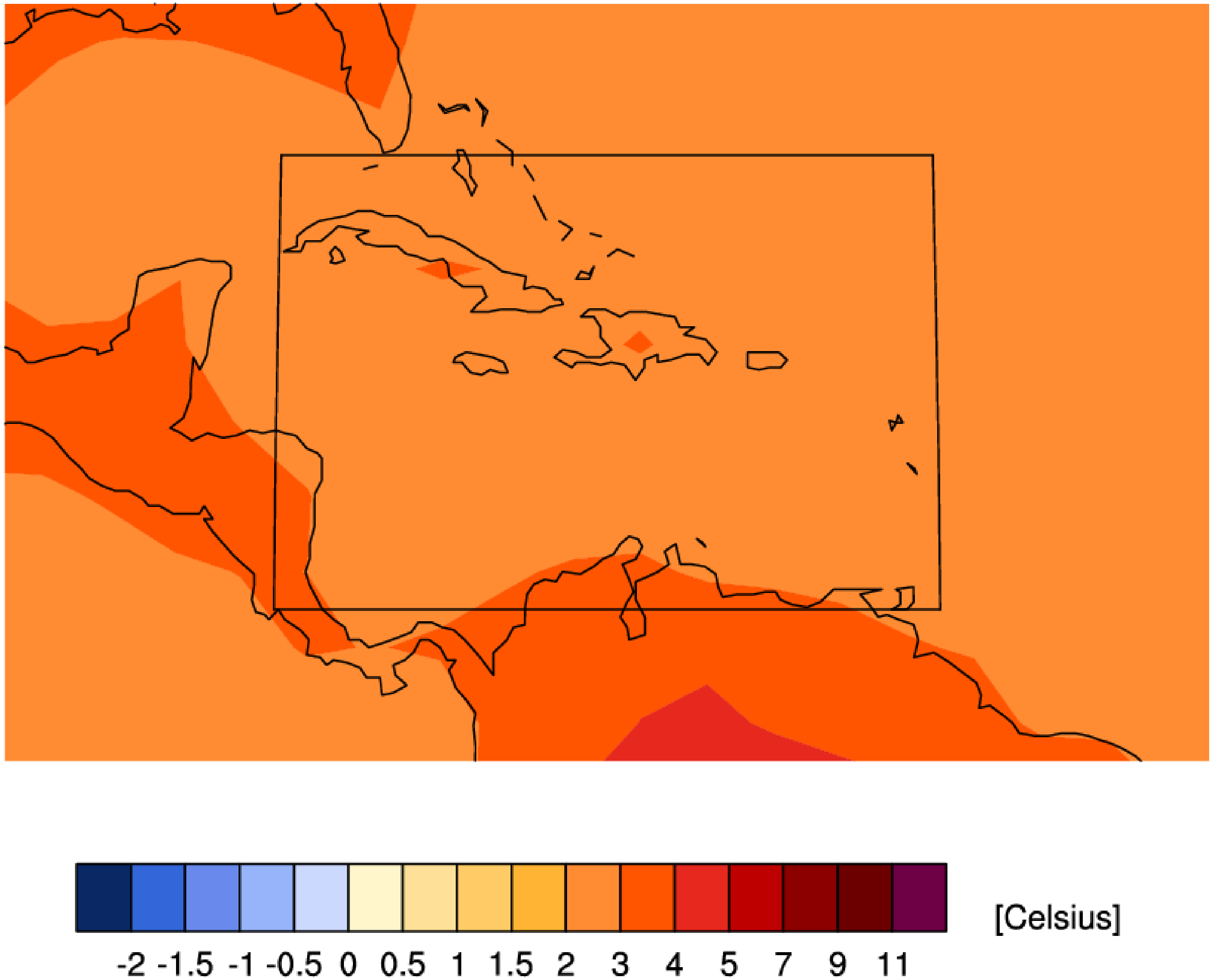


2050S RCP8.5 MAPS 5%, MEAN AND 95TH PERCENTILES

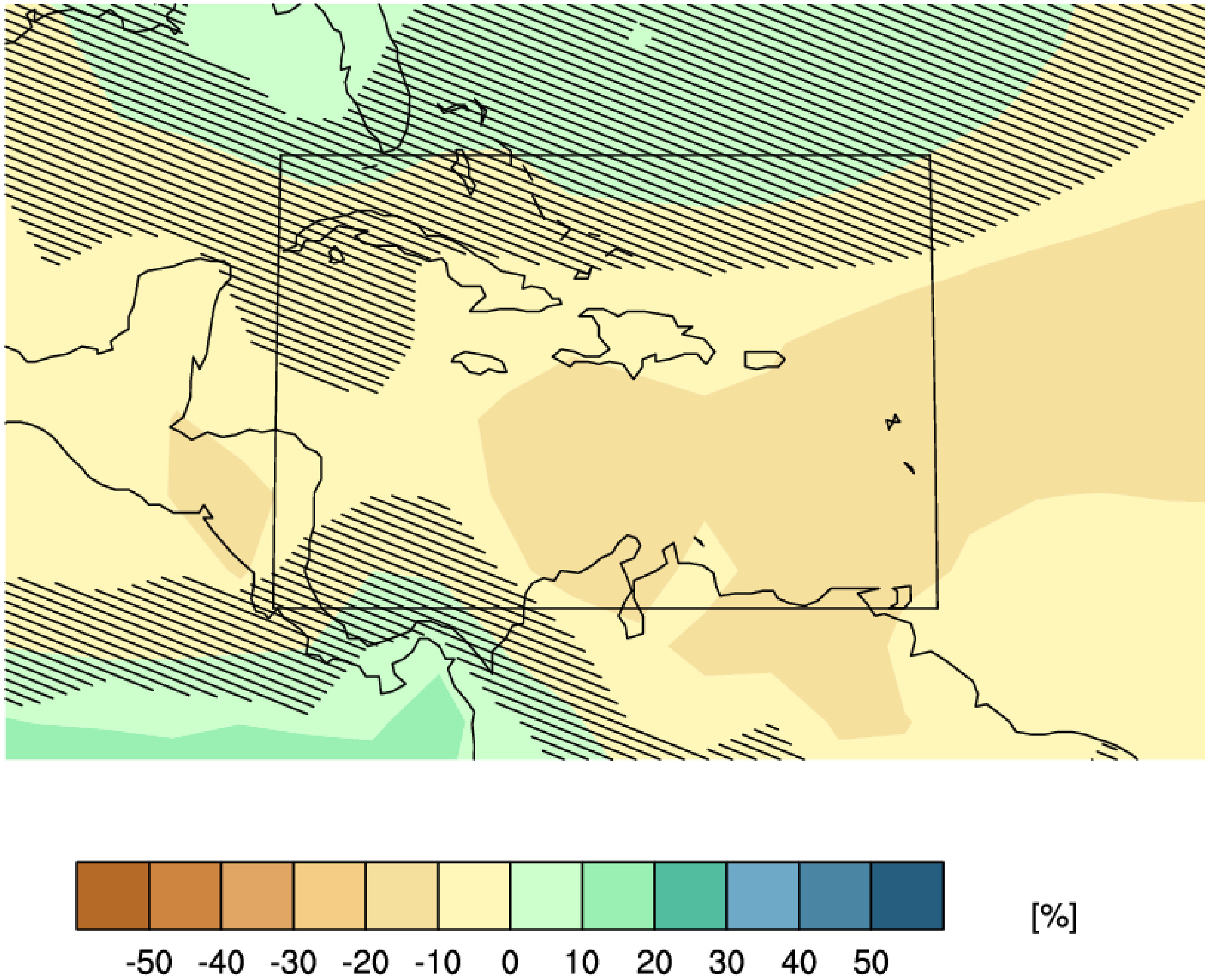



mean rcp85 temperature 2041-2070 minus 1961-1990 Jan-Dec AR5 CMIP5 subset
[Celsius]
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2 3 4 5 7 9 11

95% rcp85 temperature 2041-2070 minus 1961-1990 Jan-Dec AR5 CMIP5 subset



mean rcp85 relative precipitation 2041-2070 minus 1961-1990 Jan-Dec AR5 CMIP5 subset



Useful data sources and monitoring programmes

- **Reef watch**- volunteer survey program with sites in over 80 countries and territories worldwide (http://reefcheck.org/ecoaction/country_list.php)
- **The Global Coral Reef Monitoring Network (GCRMN)-** network of scientists and reef managers in 96 countries who consolidate status information in periodic global and regional status reports (http://www.icriforum.org/gcrmn)
- **The Atlantic and Gulf Rapid Reef Assessment (AGRRA) Program**- standardized assessment method that has been applied in over 800 coral reef locations across the Caribbean and Gulf of Mexico (http://www.agrra.org/)
- **Reef Environmental Education Foundation (REEF)**- works with volunteer divers to collect data on marine fish populations in the Caribbean and Pacific (http://www.reef.org/).
- **Coral Reef Watch -**5km resolution Satellite Coral Bleaching Thermal Stress Monitoring Product Suite (http://coralreefwatch.noaa.gov/satellite/bleaching5km/index.php)
- **ReefBase-** Global information system for coral reefs (http://www.reefbase.org/global_database/default.aspx?section=t4&region=&country)
- **CARIBSAVE**- regional and large-scale climate and development projects in the Caribbean (http://caribbean.intasave.org/Our-Projects.html).
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