Climate Modelling: The Science of Climate Change and Projections

A training Manual for delivery of a regional workshop

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Introduction

1.1. Background and Rationale

Though the Caribbean contributes less than 1% of Green house gases (GHG's), the region has peculiar characteristics which make it especially vulnerable to the effects of climate change. Some of these challenges include high transportation and communication costs, high import costs, a lack of economies of scale, susceptibility to natural disasters and climate related events and a heavy dependence on a limited natural resource base e.g. agriculture, fishing, tourism and mining. These challenges hinder growth and sustainable development because the small island developing states that make up the Caribbean have fewer resources to adapt: socially, technologically and financially.

It is therefore important that decision makers at the regional, national and local levels have specific and accurate data on the likely impacts of climate change especially at the sector level. Some of this knowledge hinges on information provided from future projections of Caribbean climate, with these future projections coming from climate modelling efforts. The challenge is that some decision makers do not use (even when the desire is there) available modelled data for a variety of reasons. These include an insufficient understanding of the data produced by modelling, insufficient understanding of the modelling process, scepticism about inherent limitations and uncertainties associated with the data, and a lack of knowledge about how to apply the data in specific sector contexts.

There is a real need, then, for a thorough understanding of climate modelling and climate projections – the process, the results and how to interpret and use the output. This training manual describes in summary the information required to run a multi-day workshop on **Climate Modelling: The Science of Climate Change and Projections.**

Specific workshop objectives are provided below which guide the construct for both the proposed workshop and this manual. The proposed workshop will in general provide persons interested in gaining basic knowledge of climate change, climate change modelling, climate change projections, and the use of climate model outputs in assessing vulnerability and adapting to climate change with an avenue for gaining such information. The workshop (and this manual) will assume the Caribbean as its context and as the source of its examples. As such the workshop should aid in decision making in the region at the local, national and regional levels.

It is anticipated that participants will include (among others) community workers, sector representatives, meteorological service representatives, civil servants, business professionals and university students. There are therefore no specific academic requirements, but participants should be mid-level professionals with a good understanding of Mathematics, Physical and Biological Sciences and some prior basic knowledge about climate change. Above all there should be an interest in the subject area and a willingness to be engaged and to learn.

1.2 Workshop Objectives

The overall aim of the workshop **Climate Modelling: The Science of Climate Change and Projections** is to provide workshop participants with the knowledge and capacity to interpret and use climate model outputs. It is intended that such an understanding will in turn aid the participants in further understanding how climate change may impact various sectors of importance to the Caribbean region including the agriculture, water, coastal (fisheries, tourism) and health sectors, and therefore aid in decision making.

In order to do the above participants are expected to gain from the workshop (i) information (including a basic understanding of climate change, models, projections, relevant related climate change issues) (ii) skills (the ability to create if necessary future scenarios for their country or location given climate change data from a Global Climate Model (GCM) or a Regional Climate Model (RCM), and (iii) confidence (in using and interpreting climate model data).

The workshop content must therefore cover the basics of climate change and climate models and any issues related to climate change given the largely small island context of the Caribbean.

Some specific objectives of the workshop include:

- Understanding the interconnected nature of the climate system.
- Understanding what is meant by climate change and what is causing it.
- Appreciating how climate change has already manifested itself in the Caribbean.
- Recognizing the climate model as a tool for ascertaining possible future climates.
- Differentiating between Global Climate Models (GCMs) and Regional Climate Models (RCMs).
- Differentiating between scenarios and representative concentration pathways (RCPs).
- Examining how climate is projected to change in the Caribbean
- Using and interpreting model data.
- Appreciating the limitations and uncertainties of model data.
- Capturing the difficulties in communicating climate science information.
- Appreciating the mechanisms for using climate model data in sector impact models

1.3 Design of the Course

Given the objectives above it is proposed that the course content be delivered in four modules. The modules are described in brief below with more details provided in the subsequent chapters of this manual.

- ***Module 1 - Climate Change Basics***
  This module will provide an introduction to the earth's climate system and basic climate change science including the role of greenhouse gases. It includes an exploration of how climate change has already manifested itself on the global scale and within the region. It is necessary context for understanding modelling.

- ***Module 2 - Modelling and Projections I: Basics***
  This theme gives an introduction to climate modelling including types of models and an exploration of how and why modelling is done. This module will include an exploration of scenarios and ensemble modelling, as well as how future climates are represented. Participants will also learn about climate change projections for the Caribbean region from both global and regional models.

- ***Module 3 - Modelling and Projections II: Other Considerations***
  With a good grasp on the different types of models and how to interpret modelled data, this module will explore some additional issues to be borne in mind including limitations and uncertainties, and how the data may be used in impact studies.

- ***Module 4 – Other Related Issues***
  Finally, participants will be exposed to related issues including how modelling fits into integrated assessments of climate impacts, the difficulties of communicating climate change science information (e.g. that from the models), the economics of climate change for the Caribbean region, and where climate change modelling is headed in the region.

- ***Module 5 – Optional Topics***
  This module is optional, dependent on available time, but is potentially very useful. The module will also introduce concepts of vulnerability, adaptation and mitigation. It, for example, can hone in on specific sector examples and case studies utilising the expertise and resources local to the country in which the workshop is being staged. Examples of some potential topics for discussion are provided in this manual.

Each module will have Units, where each Unit describes a self contained lecture or a Learning Exercise. It is not proposed that modules must be allocated equal time for delivery, rather it is foreseen that Modules1, 2 and 3 will take up most of the workshop time given the specific focus of the Workshop on climate models. Module 5 can be tailored appropriately to available expertise or priority sectors dependent on the location of the workshop, or can be excluded all together according to available time.

Proposed Units in each module are given in Table 1 below along with summary and learning outcomes.

Table 1 Course modules and units.

Lecture	Description	Learning Outcome
	Module 1: Basics of Climate Change	
Unit 1.1 The Earth as an Integrated System	Linkages between Land, ocean, atmosphere.	An appreciation for the earth's components and why change in one impacts another.
Unit 1.2 All you need to know about Greenhouse Gases	Greenhouse gases, greenhouse effect, anthropogenic contribution, global warming.	Knowledge of why and how the earth has warmed.
Unit 1.3 Learning Exercise. Emissions Targets	Activity: Exploring emissions targets (including that proposed by SIDS) and what that will mean.	Take home message: Emissions targets impact future concentrations. What the Caribbean is asking for.
Unit 1.4 Global warming and Global Environmental Change	Insights from the IPCC report on how global warming will impact global temperatures, rainfall, sea levels, extreme events.	An appreciation for historical climate change at the global level.
Unit 1.5 Global warming and Regional Environmental Change	Insights from regional research on how global warming will impact Caribbean temperatures, rainfall, sea levels, extreme events.	An appreciation for historical climate change at the global level.
	Module 2: Modelling and Projections 1- Basics	
Unit 2.1 Deducing the Future: Scenarios and RCP's	SRES scenarios, RCPs, what do they mean.	Scenarios are storylines about emissions.
Unit 2.2 Deducing the Future: GCM's and RCM's	GCMs and RCMs as tools for producing climate projections	Models are useful tools for producing climate scenarios.
Unit 2.3 Projections for the Caribbean	Examples of Projections for the Caribbean from an RCM	An appreciation for what a model projection looks like.
Unit 2.4 Learning Exercise 3 and discussion: Scenarios	Activity: Exploring what a scenario means.	Take home message: Can't predict the future but can project.
Unit 2.5: Build your own scenario: GCM's	Activity: Creating a climate change scenario for your country using GCM data.	An appreciation for scenarios from GCMs
	Module 3: Modelling and Projections II- Other Considerations	
Unit 3.1 Deducing the Future from Models: Other Model Variables	Besides temperature and rainfall, what else can models project.	Other variables are important.

Unit 3.2 Model Limitations and Uncertainties	Errors, ranges, what the model can and can't do.	Interpreting the data with care.
Unit 3.3 Variability and Seasonal Predictions	Everything isn't long term change. Interannual and decadal variability.	Variability is important for the now as well.
Unit 3.4 Impact Models	Using Model data in other sector models	Assessing needs by sector and relating to climate model data output.
Unit 3.5 Learning Exercise: Climate Noodle Soup	Activity: Variability in my country data, what might cause it.	Take home message: Variability is important for the now as well.
	Module 4: Other Related Issues	
Unit 4.1 The Caribbean Modeling Initiative	Where the science of modelling is headed within the Caribbean region.	The importance of collaboration.
Unit 4.2 Institutions of Climate Change	The main actors in regional climate change research and work	Who to call.
Unit 4.3 The Cost of Climate Change	The cost of action or inaction.	Climate change has economic implications.
Unit 4.4 Communicating Climate Change	The challenges of communicating climate change science.	Different media for different messages.
	Module 5: Optional Units	
Unit 5.1: Vulnerability	Vulnerability, adaptation and resilience.	Appreciation for the common terminology.
Unit 5.2: Integrated Assessments	Integrated Assessments	What is meant by integrated assessments.
Unit 5.3: Regional Adaptation	Are we doing anything to adapt in the region? Approach and examples.	Examples of adaptation in our region.
Unit 5.4: Introduction to Climate Change Mitigation	Mitigation – what is that? Methods and Technologies for Climate Change Mitigation.	An appreciation for mitigation as important for Caribbean countries as well.

The workshop can be delivered over five or up to eight days depending on how much of Module 5 is included. ***Appendix A*** has a sample schedule for delivering the workshop over eight days.

It is proposed that delivery be through a combination of traditional face to face lectures, interactive exercises, discussions, case studies, assignments and a field trip. Whereas lectures cover the theoretical aspects of the course the interactive learning exercises reinforce the key points. Efforts should be made to emphasize methodological processes and case study applications that can be replicated in planning and decision making processes within sectors.

It is suggested that a course assessment be done e.g. a final test of multiple choice questions. This can be delivered electronically. Participants should be awarded a certificate e.g. of distinction, merit, completion and participation.

1.4 About this manual

The purpose of this manual is twofold. On the one hand it is produced as a guide for how to set up and structure delivery of a workshop of this nature. In this case, the Appendices are important as they provide a suggested timetable (***Appendix A***); tips for delivery of the workshop (***Appendix B***) and useful online resources (***Appendix C***).

On the other hand this manual is also a guide to the content such a workshop should cover. The ensuing sections i.e. Sections 2 through 5, detail firstly for each module the learning objectives, the expected learning outcome for the participant and a suggested flow for the ensuing Units. Each section also provides an outline of content to be included in each of the proposed Units which comprise the module under examination. It is to be pointed out that it is impossible to provide all the content for each unit in this manual. Each Unit can themselves be the subject of whole books or manuals. As such the content provided in this manual for each Unit simply highlights key ideas that should emerge from a presentation on the Unit topic and describes some key points that can be made. The points are not to be taken as exhaustive but rather as the minimum information to be given (if nothing else). There is much scope for expanding greatly the points made.

The manual, then, is only meant as a guide for the presenter but does not remove the need for the presenter to prepare further to match context, audience and learning levels. Notwithstanding, it is our belief that the guide is comprehensive enough for use by anyone planning a similar workshop, and as such will prove very useful.

The Manual follows, then, the modular design of the course. It may be used in modules or as a whole, depending on the purpose and duration of the training. The content is designed to be applicable at different levels – from the regional, national, and local levels. Though it is strongly recommended that the order of the modules be followed as in the manual, there can be deviations as deemed appropriate and/or necessary.

Module 1

Climate Change Basics

Module Summary

Aims and Learning Outcomes

This module aims at:

- Providing basic information about the components of the climate system, and important cycles.
- Providing information about causes for variation in climate change including natural and anthropogenic causes.
- Giving the participant an understanding of the role of greenhouse gases in the atmosphere and how changes in concentration affect global temperatures.
- Describing how warmer global temperatures impact climate globally
- Describing how warmer global temperatures impact climate regionally.

At the end of the module the trainee will be familiar with:

- The concept of the earth's climate system as an integrated whole.
- The link between greenhouse gas emissions from human activities and climate change.
- The different emissions targets being advocated by developed, developing countries, the Caribbean.
- The historical manifestation of climate change globally.
- The historical manifestation of climate change in the Caribbean.

Module Flow

Unit 1.1	**The Earth as an Integrated System**	**The course should start by describing the components of the climate system and by making the point that alteration of one component impacts other components.**

Unit 1.2	**All You Need to know about Greenhouse Gases**	**An introduction to climate change and the role that greenhouse gases play naturally and in anthropogenic (human induced) climatic change. That is, relating greenhouse gas concentrations to warming and global warming.**

Unit 1.3	**Learning Exercise: Emissions Targets**	**Relating the concept of greenhouse gases to emissions targets being advocated for globally, including that being posited as the Caribbean position. Why these targets? What do they mean in terms of temperatures?**

Unit 1.4	**Global Warming and Global Environmental Change System**	**So if the earth warms what will happen? A look at how global warming has manifested itself historically in trends in global temperatures, rainfall, seal level rise and extreme events.**

Unit 1.5	**Global Warming and Regional Environmental Change System**	**So if the earth warms what will happen in the Caribbean? A look at how global warming has manifested itself historically in trends in regional temperatures, rainfall, seal level rise and extreme events.**

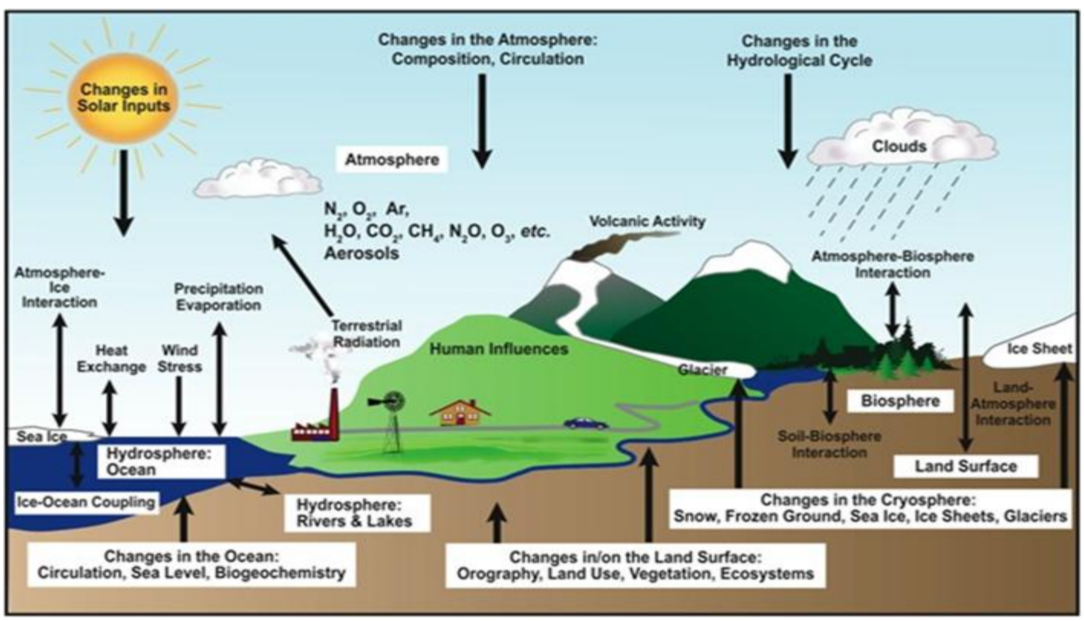
Unit 1.1 The Earth as an Integrated System

Key Ideas:

- **The earth system is made up of components – namely the atmosphere, land surface, ocean, ice, and vegetation and living things.**
- **The different components are connected though Cycles – for example the Hydrological cycle and the Carbon Cycle.**
- **We can talk of balance with respect to a number of the earth's characteristics e.g. its energy. Cycles help maintain balance through exchanges.**
- **Changes in the components of the atmosphere can occur over short and long timescales due to external forcings. The change is called a response.**
- **Feedbacks can amplify or diminish a response due to a forcing.**

Key Points

The constituent parts of the earth system are called its **components**. These include the atmosphere, land surface, ocean, ice, and vegetation and living things**.** They are illustrated in Figure 1 below. Some facts about each are given in Table 2.



Solomon et al. (2007)

Figure 1 Components of the earth

Table 2 Some facts about the Components of the earth system.

Atmosphere	Ocean	Land Surface	Vegetation	Ice
78% nitrogen and 21% oxygen Other elements make up < 1% Air is never completely dry and water can be up to 4% of its volume. Residence time of water vapor in the atmosphere is ~10 days. It's comprised of many different layers, including stratosphere, troposphere, ionosphere, etc.	Oceans cover about 70% of the Earth's surface. The oceans contain roughly 97% of the Earth's water. Oceans moderate the earth's temperature by absorbing incoming solar radiation (stored as heat energy). The always-moving ocean currents distribute this heat energy around the globe. 94% of life on Earth is aquatic.	There is less land than there is water. Close to 40% of the Earth's land surface is presently used for cropland and pasture The planetary surface undergoes reshaping over geological time periods because of tectonics and erosion	Is very climate dependent. Trees are the longest living organisms on the planet and one of the earth's greatest natural resources. Vegetation keep our air supply clean, reduce noise pollution, improve water quality, help prevent erosion, provide food and building materials, create shade, and improve aesthetics	The cryosphere includes all forms of frozen water on the Earth's land or sea surfaces Seasonal snow cover is the largest component of the cryosphere. Glaciers and ice sheets cover about 10% of the Earth's land area. Glaciers and ice sheets store about 75 percent of the world's freshwater.

The **Hydrological Cycle** is an important cycle which joins different components of the atmosphere. It ensures that water never leaves the earth as it is constantly being cycled through the atmosphere, ocean and land. It is driven by the sun and is crucial to the existence of life on our planet. See Figure 2 below.

The **Carbon Cycle** is a second common cycle in the earth system. There are four primary reservoirs for carbon. It can be in the atmosphere. It can be in land-living animals and plants or the by-products of these. It can be in the oceans, including in animals and plants living there. Finally, it can be in the sediments, including in fossil fuels. The different places carbon can be are connected by pathways of exchange. This is all referred to as the carbon cycle. See Figure 2 below.

We can talk of the **Energy Balance** of the earth. This occurs when inflows and outflows of heat are equal. If this is so we say the earth is in thermal equilibrium (i.e. the earth is not getting warmer or cooler) or the overall heat budget of the earth is balanced. Cycles are an important part if achieving balance through exchange.

Changes in a component of the earth system (e.g. the atmosphere) can occur over both short and long timescales due to external factors. The external factors are called **forcings**. The change is called a **response**. A forcing need only change one component but because components are linked through cycles all other components may have a response. Table 3 gives four types of forcings.

A **feedback** is a process that amplifies or diminishes a change already underway due to a forcing. There can be positive feedback (amplifies change) and negative feedback (diminishes change).

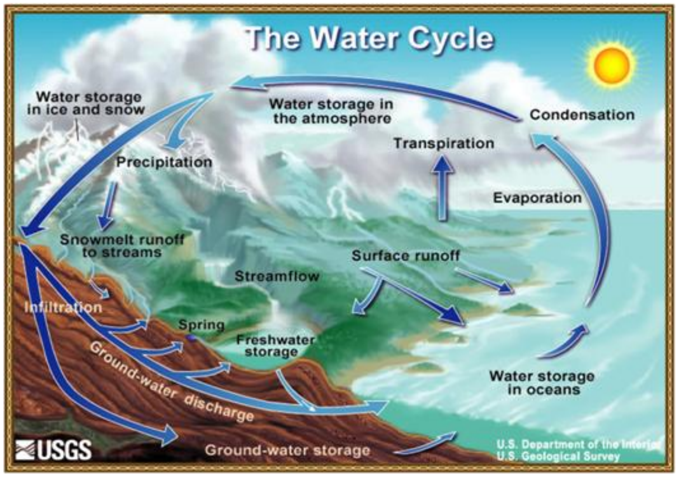


Figure source: http://ga.water.usgs.gov/edu/watercycleprint.html

The sun heats up liquid water and changes it to a gas by the process of evaporation. Water that evaporates from Earth's oceans, lakes, rivers, and moist soil rises up into the atmosphere. The process of evaporation from plants is called transpiration. As water (in the form of gas) rises higher in the atmosphere, it starts to cool and become a liquid again. This process is called condensation. When a large amount of water vapor condenses, it results in the formation of clouds. When the water in the clouds gets too heavy, the water falls back to the earth. This is called precipitation. When rain falls on the land, some of the water is absorbed into the ground forming pockets of water called groundwater. Most groundwater eventually returns to the ocean. Other precipitation runs directly into streams or rivers. Water that collects in rivers, streams, and oceans is called runoff.

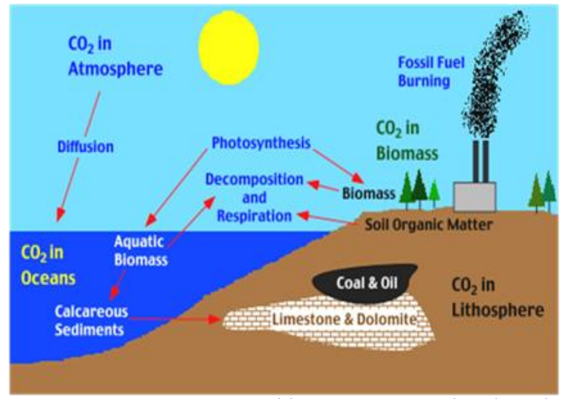


Figure source: http://geo.arc.nasa.gov/sge/casa/cquestwebsite/images/carbon_cycle.jpg

Plants remove carbon from the atmosphere and from sea water by photosynthesis. Animals eat the plants and release the carbon back into the environment again through respiration. Burning and decay are two other processes that move carbon from living organisms to the non-living environment and the atmosphere. Carbon from living and dead biological organisms are moved into the atmosphere in two forms - as CO_2 and as methane. Both are greenhouse gases. Burning fossil fuels release carbon into the atmosphere.

Figure 2 The Hydrological Cycle and the Carbon Cycle.

Table 3 Four Climate Forcings of the Earth System

Tectonic Processes	Earth-orbital changes	Changes in the strength of the sun	Anthropogenic or Human Induced
These are generated by the earth's internal heat and affect its surface by means of processes that alter the basic geography of the earth's surface. Examples include the movements of continents across the globe, the uplift of mountain ranges, and the opening and closing of ocean basins. These processes change very slowly over millions of years or much longer.	These result from variations in the earth's orbit around the sun. The changes alter the amount of solar radiation received on earth by season and latitude. Orbital changes occur over tens to hundreds of thousands of years.	These affect the amount of solar radiation arriving at the earth. For example the strength of the sun has slowly increased over the time the earth has existed. Shorter term changes occur over decades, centuries, and millenia and are partially responsible for climatic changes at the shorter timescale.	The unintended by product of agricultural, industrial and other human activities by way of additions to the atmosphere of materials such as carbon dioxide and other gases, sulfate particles and soot.

Unit 1.2 All You Need to Know About Greenhouse Gases

Key Ideas:

- **There is an energy balance between incoming solar radiation (from the sun) and outgoing infrared radiation (from the earth's surface).**
- **The Greenhouse Effect occurs because certain gases called greenhouse gases are relatively transparent to the wavelengths of solar radiation, while they absorb infrared radiation from the earth. It naturally keeps the earth warm.**
- **Human activities are changing the amounts of greenhouse gases. Thus we are producing an enhancement of the Greenhouse Effect.**
- **There is a significant and unprecedented increase in green house gas concentration in the last century.**
- **Warming of the climate system due to human induced increases in greenhouse gases is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures.**

Key Points

The Sun warms the Earth and makes life possible. Its energy generates clouds, produces plants, keeps animals and humans warm, and drives ocean currents and thunderstorms.

In the earth's **energy budget** there is a balance at the top of the atmosphere and at the earth's surface. This keeps the temperatures of the atmosphere and earth relatively constant. The balance is illustrated in Figure 3.

There are several atmospheric gases called **Greenhouse Gases** that are transparent to visible radiation (i.e. they allow through radiation of this wavelength from the sun) but are able to absorb and emit the infrared radiation emitted by Earth's surface. The net effect of this is that they warm the Earth's surface and its atmosphere. They therefore act like the glass of a Greenhouse, and the whole effect is called the **Greenhouse Effect**.

The Greenhouse Effect is totally natural. Without it the temperature of the earth would be 33 ^{o}C lower. Thus the atmosphere acts as a nice blanket for the surface allowing life to exist on earth.

Human activities are changing the amounts of greenhouse gases i.e. they are enhancing the Greenhouse Effect by increasing greenhouse gases. Increases since 1750 are attributed to human activities. Figure 5 shows the main greenhouse gases, their pre-industrial and post-industrial concentrations and the human activity causing the change.

The effect of increasing the concentrations of the greenhouse gases in the atmosphere is akin to adding more blankets to the Earth's surface i.e. it alters the radiative forcing and makes the earth warmer. **Global warming** is the genesis of climate change.

Radiative forcing is a measure of how the energy balance of the Earth-atmosphere system is influenced when factors that affect climate are altered. Increases in carbon dioxide, CO_2, have caused the largest forcing since 1750. Figure 5 shows how the concentration of three greenhouse gases has changed over the last two thousand years. The figure also shows that variations in the concentration of the gases are mirrored by variations in global surface temperatures.

Because greenhouse gases remain in the atmosphere for many years, their effects also remain for long time.

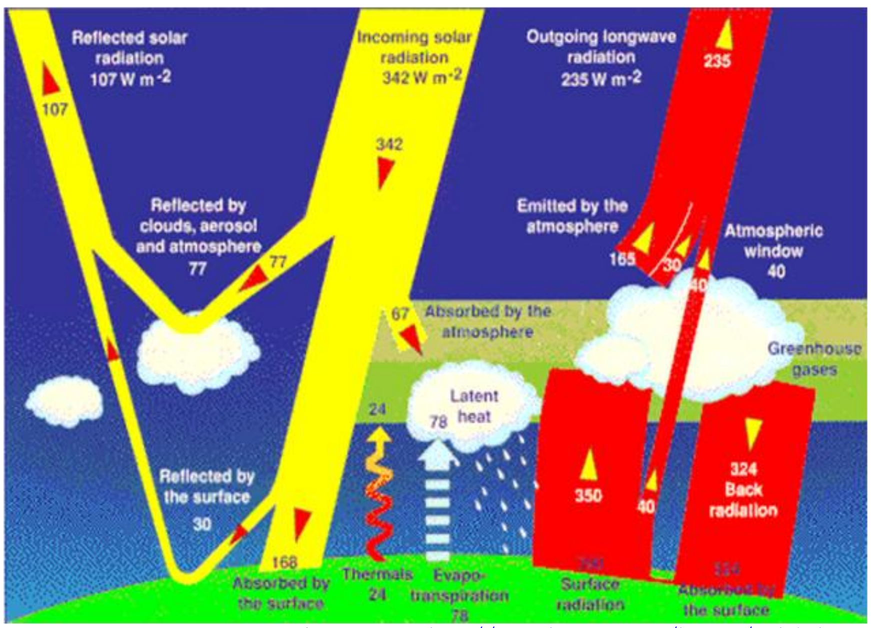


Figure source: http://ceres.larc.nasa.gov/images/rad_bal.png

At the top of the atmosphere:
Incoming shortwave = Reflected Shortwave + Emitted longwave

At the surface:
Incoming shortwave = Reflected shortwave + Net emitted longwave (emitted - incoming) + Latent heat flux + sensible heat flux

Shortwave = solar radiation

Figure 3 Energy Budget of the Atmosphere-earth system.

The main greenhouse gases

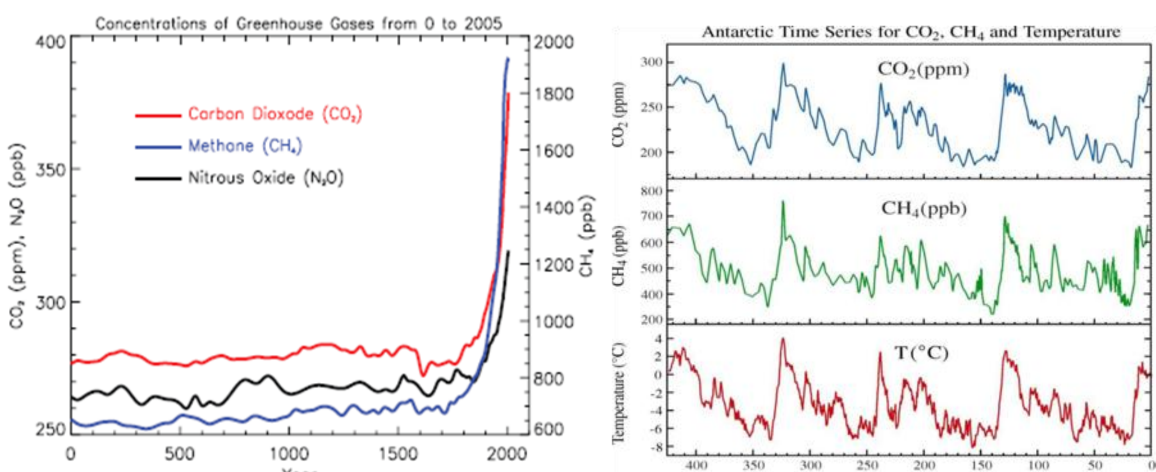
Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants. Foams
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid

Houghton et al. (1995)

Note:

- Rows 4-6 are gases that do not exist naturally. Current concentrations are associated with man-made activities.
- We must include to Water Vapor in the list. Water Vapor is the most abundant greenhouse gas in the atmosphere and has a strong effect. The surface temperature rise will increase the evaporation and the water vapor in the atmosphere, which will enhance the initial warming *(a positive feedback)*.

Figure 4 Schematic of main greenhouse gases.



Solomon et al. (2007)

Figure 5 (Left) Changes in greenhouse gas concentrations over the last 2000 years. (Right) Variations in greenhouse gas concentrations and temperature.

Unit 1.3 Learning Exercise: Emissions Targets

Key Ideas:

- **Greenhouse gas concentrations are directly linked to temperatures on the earth surface.**
- **For this reason, developed and developing countries and various lobby groupings advocate capping emissions or setting targets going into the future which would stabilize greenhouse gas concentrations and limit the rise in temperature seen.**
- **The Alliance of Small Island States is advocating targets that would limit the temperature increase to 1.5 °C.**

What's the Limit?

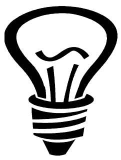
A number of useful simulations exist on the web to help us connect greenhouse gas emission with greenhouse concentrations and temperature rise. This exercise takes you through a simple simulations to get you thinking about what the greenhouse gas concentration limits should be or if there should be any limits at all. It is to be done in pairs.

Activity A

1. Open a browser (Firefox, Internet Explorer, Google Chrome) and enter the following URL : http://climateinteractive.org/simulations/climate-momentum-simulation/climate-momentum
2. Note that there is a slider at the bottom and when you move it to the right the values change.
3. Can you fill in the Table below.
4. Which target would you advocate for?
5. Look up online what targets the small island developing states are advocating. (Google ***1.5 to stay alive***). You may also want to look at what other countries/groupings are advocating for.
6. Discuss your results with the pair nearest you. Is there an agreement between everybody?

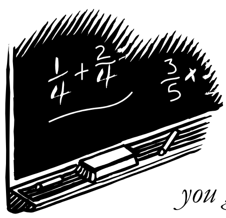
Climate Target	**Climate emissions in 2100 (tons of Carbon)**	**CO_2 concentration in 2100 (parts per million)**	**Global temperature change in 2100 (degrees Celsius)**	**Mena global sea level rise (mm)**
BAU - Assuming no significant action to avoid climate change.				
March 09 - Assumes countries follow their publicly stated proposals for CO2 emissions reduction.				
Flatten - Global CO2 emissions are level by 2025 but do not fall.				
Modest - Global CO2 emissions decrease modestly: 29% below 2009 levels by 2040.				
80% - An 80% reduction of global fossil fuel plus a 90% reduction in land use emissions by 2050.				
95% - A 95% reduction of CO2 emissions by 2020.				

Unit 1.4 Global Warming and Global Environmental Change System



Key Ideas:

- **Climate change manifests as global warming due to the increased greenhouse gas concentrations.**
- **Global warming results in other changes in the earth's global climate system. These include changes in rainfall, sea levels and extreme events.**
- **All these changes have been observed in the last century.**



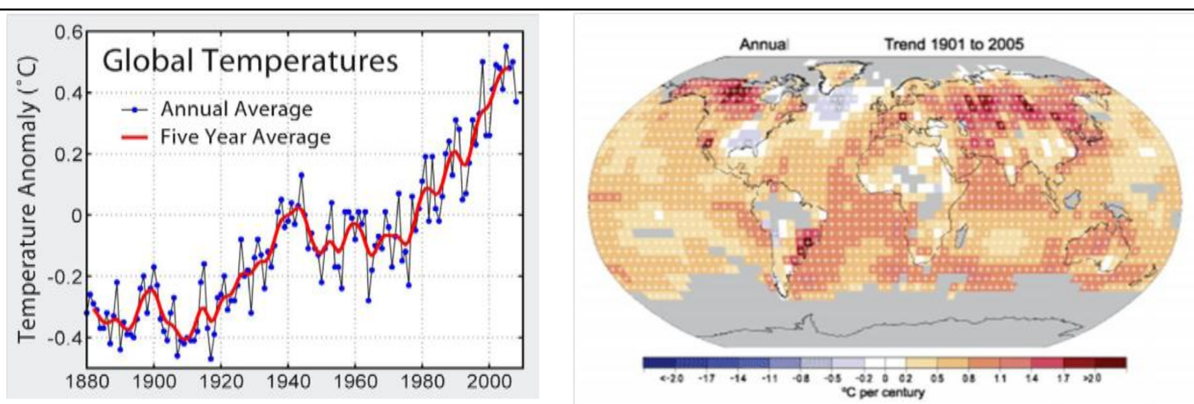
Teaching Tool

For this unit we suggest using a Climate Change Quiz similar but shorter than that given in Appendix B. Base it on the material of this Unit. Give it before going over the material so participants can test their knowledge about how climate change is manifesting itself. Then, as you go through the material, make sure to point out the correct answers.

Key Points

Global Warming is an abnormal and sustained increase in the average temperature at or near the earth's surface. It results from human activity which has been increasing the concentration of greenhouse gases in the atmosphere.

There has been a temperature rise of 0.74°C ± 0.18°C during the period 1906 – 2005. Figure 6 illustrates the rising global temperatures. The warming over the past 50 years has been at a rate of 0.13°C ± 0.03°C per decade which is nearly twice that for the past 100 years.



Houghton et al. (2001) Solomon et al. (2007)

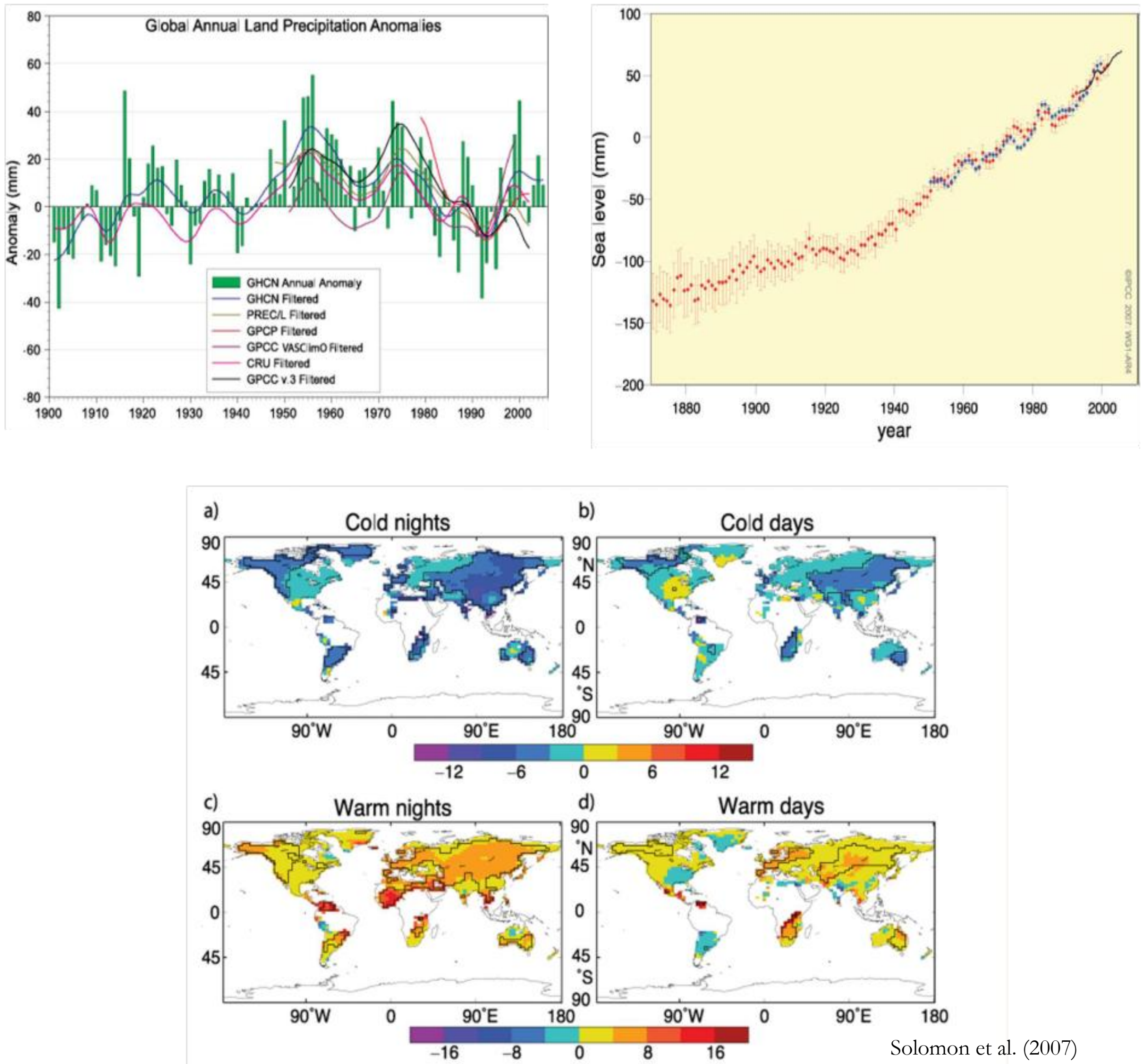
Figure 6 (Left) Global temperature anomalies since 1880. (Right) Temperature change/century 1901-2005.

The warming manifests itself as more warm days, fewer cold nights, and a lower diurnal temperature range. Mid Latitude northern and southern land masses have areas of greatest historical warming. Parts of the southeastern U.S. and parts of the North Atlantic have however cooled slightly over the last century

There are trends in other climatic variables which have manifested themselves in the last century concomitant with the warmer temperatures. Table 4 summarises some of the trends observed. It is supported by Figure 7.

Table 4 Observed trends in global climate.

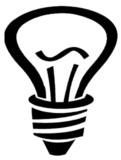
Hydrology	**Extremes**
Globally-averaged land-based precipitation shows a statistically insignificant upward trend (see Figure 7) Increases in annual precipitation have occurred in the higher latitudes of theNorthern Hemisphere and southern South America and northern Australia. Decreases have occurred in the tropical region of Africa, and southern Asia. There is agreement between measured changes in precipitation and observed changes in stream flow, lake levels, and soil moisture. There have been decreases in the North Hemisphere's snow cover.	Decreases in the number of unusually cold days and nights have been observed (see Figure 7). Similarly decreases in the number of frost days in the northern hemisphere have been observed. The extent of regions affected by droughts has increased as precipitation over land has marginally decreased. Generally, numbers of heavy daily precipitation events that lead to flooding have increased, but not everywhere. In areas such as eastern Asia, extreme precipitation events have increased despite total precipitation remaining constant or even decreasing somewhat. Tropical cyclone activity seems to have generally increased over the last half of the 20th century in the northern hemisphere, but decreased in the southern hemisphere. Hurricane activity in the Atlantic has shown an increase in number since 1970 with a peak in 2005.
Sea Level Rise	
Global mean sea level has rising at an average rate of 1.7 ± 0.5 mm/yr over the past 100 years (see Figure 7) Increases are mainly due to thermal expansion and contributions from melting alpine glaciers. Updated measurements using only the period when satellite measurements have been available indicate the rate of SLR has now reached 3.4±0.7 mm/year.	



Solomon et al. (2007)

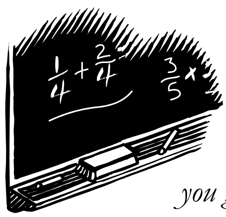
Figure 7 Trends in (top left) global precipitation anomalies; (top right) global sea levels; (bottom) cold and warm days and nights.

Unit 1.5 Global Warming and Regional Environmental Change System



Key Ideas:

- **Climate changes can be seen in the Caribbean region's climate system.**
- **These include changes in rainfall, sea levels and extreme events.**
- **All these changes have been observed in the last century.**



Teaching Tool

For this unit we suggest using a Climate Change Quiz similar but shorter than that given in Appendix B. Base it on the material of this Unit. Give it before going over the material so participants can test their knowledge about how climate change is manifesting itself. Then, as you go through the material, make sure to point out the correct answers.

Key Points

Between 1996 and 2006 the Caribbean contributed less than 1% to CO_2 Emissions from Energy Consumption.

Yet, average annual temperatures in the Caribbean have increased by more than 0.56°C over the period 1900-1995. Mean air temperature has risen by 0.6°C during the past 45 years. The region has also seen more warm days, more warm nights and fewer cool days and cool nights. Similar to the global case the changes over land for the Caribbean exceed those of the oceans.

Other changes in precipitation, sea levels and extreme events have been observed for the Caribbean region. Some changes are noted in Table 5.

Table 5 Trends in Caribbean climate

Rainfall	Sea Level Rise	Extremes
Rainfall data for the 19th Century shows large seasonal, inter-annual, and decadal-scale variability. A 250 mm declining trend in average annual rainfall has been seen over the past 50 years. It is not statistically significant.	The global sea surface rose by 1.7±0.5mm/year over the period 1961 – 1993. SLR trends in the Caribbean have been similar to global trends over this same period.	Although total precipitation showed a slight decrease, the number of heavy rainfall events has increased between 1950 and 2000. For the same period the number of consecutive dry days has been decreasing. Tropical storm and hurricane frequencies vary considerably from year to year, but evidence suggests substantial increases in intensity and duration since the 1970s.

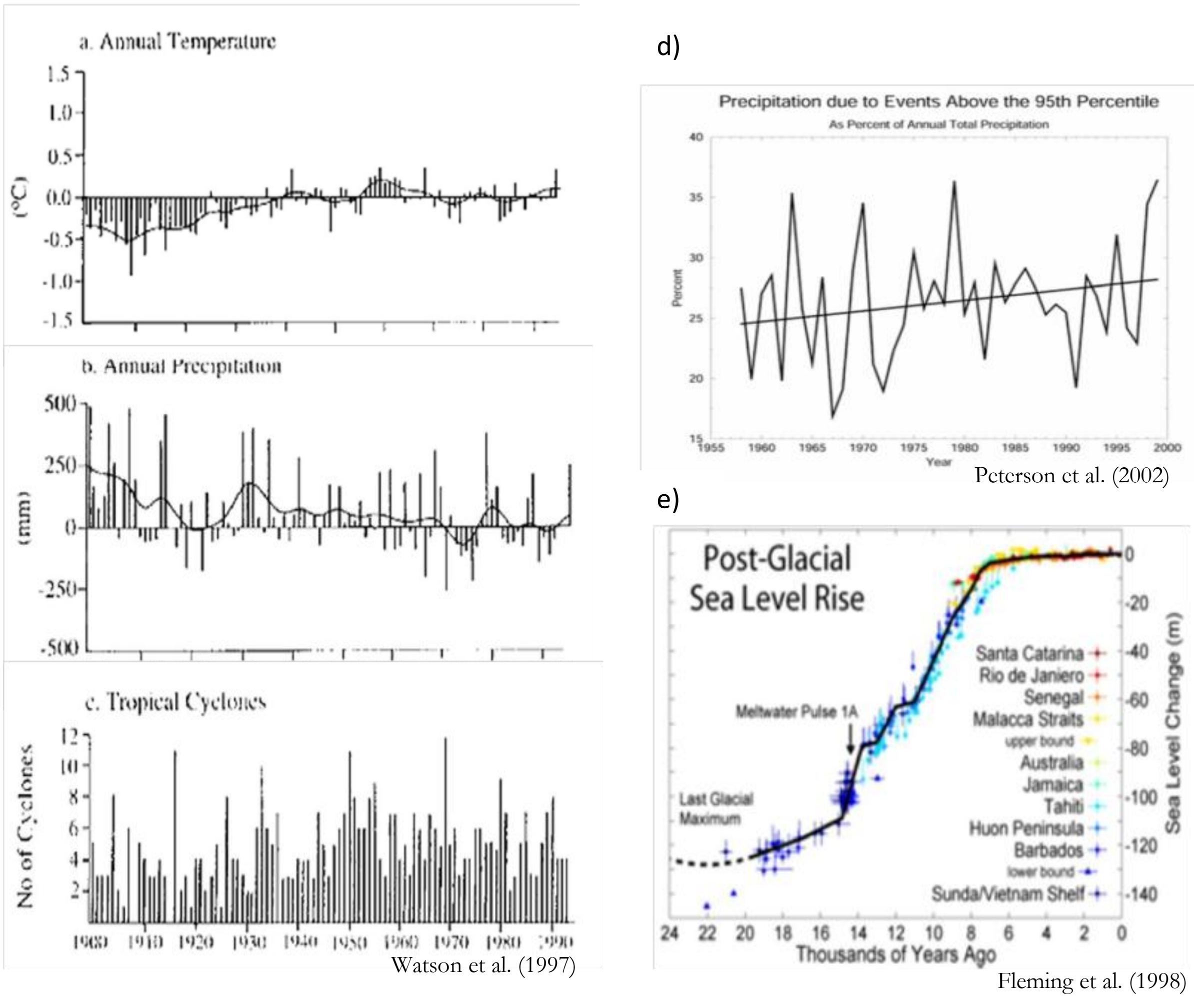


Figure 8 Trends in Caribbean a) temperature anomalies b) rainfall anomalies c) tropical cyclones d) heavy precipitation events e) sea level rise.

Module 2

Modelling & Projections 1: Basics

Module Summary

Aims and Learning Outcomes

This module aims at:

- Describing how projections are made of future climate using climate models.
- Discussing scenarios and their role in climate projections.
- Discussing Representative concentration pathways (RCPs)
- Giving the participant an understanding of what global and regional climate models are.
- Describing how scenarios + models = future projections.
- Providing insight into future climate projections for the Caribbean

At the end of the module the trainee will be familiar with:

- The concept of scenarios as storylines.
- The distinction between a regional and global model..
- How future climate projections are expressed.
- The methodology for constructing simple projections from model data..

Module Flow

Unit 2.1	**Scenarios and RCPs**	**We do not know the future so we need some storylines of possible 'futures'. Scenarios represent equally plausible futures which yield differing amounts of emissions.**

↓

Unit 2.2	**GCMs and RCMs**	**The emissions from various scenarios are used in climate models. The models simulate future climates for a range of scenarios. Whereas global models simulate the entire globe, regional models simulate smaller regions like the Caribbean.**

↓

Unit 2.3	**Projections for the Caribbean**	**So based on the models what can we expect for the Caribbean region in the future? Some ideas are provided.**

Unit 2.4	**Learning Exercise: Which Scenario?**	**Do any of the scenarios really represent the situation in the Caribbean?**

Unit 2.5	**Learning exercise: build your own future scenario**	**Now that you understand about projections, can you use climate data from a model to create a simple scenario for your county?**

Unit 2.1 Scenarios and RCPs

Key Ideas:

- **Scenarios are storylines about how the world will develop.**
- **Scenarios are divided into families according to possible global development pathways.**
- **Each scenario corresponds to a certain amount of greenhouse gas emissions in the future. SRES stands for the Special Report on Emissions Scenarios.**
- **All scenarios are plausible.**
- **Representative Concentration Pathways (RCPs) are a new generation of scenarios.**

Key Points:

When the IPCC was beginning to write Assessment Reports, they commissioned **scenarios** i.e. they literally convened scientists and modellers, provided them with a terms of reference, and set them task of developing scenarios of future emissions. They then approved the scenarios developed for use in modelling studies and used results in reports.

They have been many scenarios over the years but the most popular are the SRES scenarios. **SRES** stands for the Special Report on Emissions Scenarios. To get the possible future emissions the scientists assumed a range of possible socioeconomic futures. They examined what socioeconomic driving factors can change emissions in the future, how these are these likely to change and what the emissions will look like under these changes.

For convenience they divided the range of possibile socioeconomic futures into families with letter names. Each family has a distinct story line and each scenario family corresponds with a different emissions future. The four SRES scenario families that share common storylines are illustrated as branches of a two-dimensional tree (see Figure 9). The two dimensions indicate the relative orientation of the different scenario storylines toward economic or environmental concerns and global and regional scenario development patterns, respectively. The A1 storyline branches out into different groups of scenarios to illustrate that alternative development paths are possible within one scenario family.

Climate models simulate future climate based on the future emissions generated from the scenarios i.e. Model + Scenario = Future climate. Ideally one should simulate future climates using all scenarios since all are plausible. This would give a range of possible futures.

The research community is building new scenarios. They are called **Representative Concentration Pathways (RCPs).** They are scenarios that explore approaches to climate change mitigation in addition to the traditional "no climate policy" scenarios. They are based on a range of possible paths of radiative forcing as seen in the science literature.

Only four RCPs will be examined (Figure 10). As before, you can get corresponding emissions from the 4 RCPs. The lowest scenario is consistent with the aims to limit the increase of global mean temperature to less than 2°C.

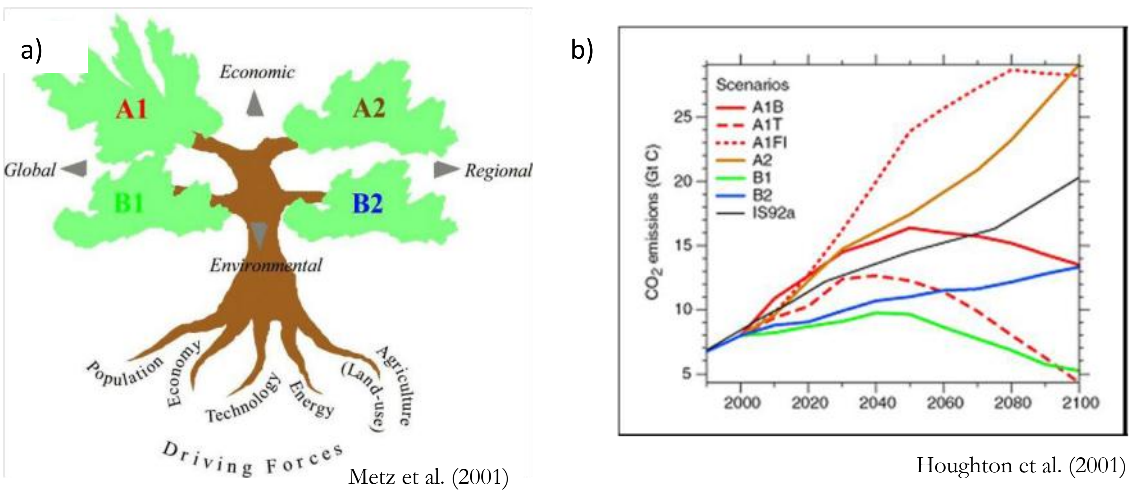


Figure 9 (a) Scenario families and socioeconomic driving forces (b) CO_2 emissiosn corresponding to different scenarios.

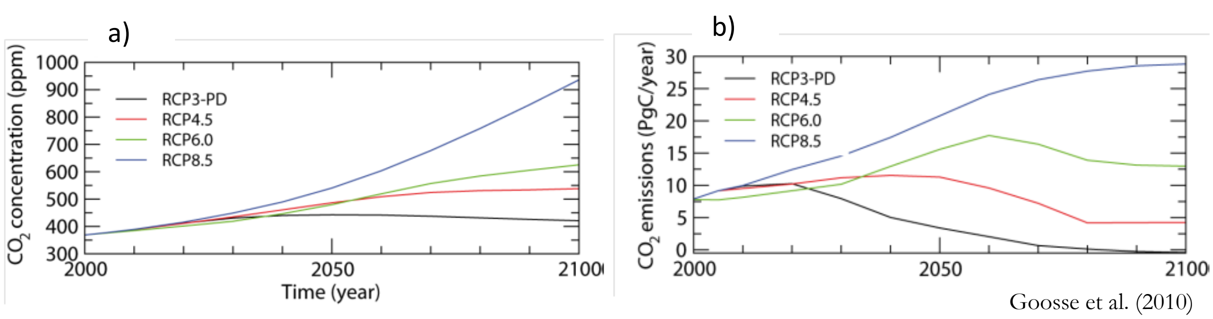


Figure 10 (a) CO_2 concentrations through the end of the century for 4 new RCPs. (b) CO_2 emissions through the end of the century for 4 new RCPs.

Unit 2.2 GCMs and RCMs

Key Ideas:

- **Models enable seasonal and long term predictions of statistical climate parameters.**
- **A general circulation model or global climate model (GCM) is a mathematical model of the general circulation of the planetary atmosphere or ocean. It is run on a computer.**
- **A regional climate models (RCMs) is similar to a GCM but is used to reproduce the main climatic features in complex terrain, where smaller scale forcing becomes important.**

Key Points:

A general circulation model (**GCM**) is a mathematical model of the general circulation of a planetary atmosphere or ocean and based on physics equations such as the horizontal momentum equation, the thermodynamic equation (conservation of energy), conservation of water, the equation of state and the continuity equation. (Mass conservation).These equations form the basis for complex computer programs which are then used to simulate the atmosphere or ocean of the Earth into the future.

A typical GCM has horizontal resolution of 1-5 degrees; and 10-30 levels in the vertical. It puts our ≈ 500,000 "basic" climate variables which can be analysed (See Figure 11).

An atmospheric GCM (**AGCM**) models the atmosphere alone (including a land-surface model) using imposed sea surface temperatures (SSTs). Oceanic GCMs (**OGCMs**) model the ocean (with fluxes from the atmosphere imposed) and may or may not contain a sea ice model. Coupled atmosphere–ocean GCMs (**AOGCMs**) combine the two models. They have the advantage of removing the need to specify fluxes across the interface of the ocean surface. These models are the basis for sophisticated model predictions of future climate, such as are discussed by the IPCC. AOGCMs are the most complex and complete climate models.

Most models include software to diagnose a wide range of variables for comparison with observations or study of atmospheric processes. Other software is used for creating plots and animations.

The main goal of regional climate models (**RCMs**) is to reproduce the main climatic features in complex terrain, where smaller scale forcing becomes important and the coarse-resolution global climate models (GCMs) are not sufficient for assessing local climate variability. RCMs have a much higher grid resolution than GCMs (see Figure 12). Very high resolution GCMs are an extremely costly alternative solution and not one that the Caribbean can pursue at present. Running an RCM over the Caribbean islands and adjacent territories is an example of the usefulness of regional models.

The nested regional climate modeling technique consists of defining a limited region (e.g. the Caribbean Region) and running a high resolution model only for that region, using the output of a GCM as boundary conditions. This technique has been mostly used only in one-way mode, i.e. with no feedback from the RCM simulation to the driving GCM.

The basic strategy is thus to use the global model to simulate the response of the global circulation to large scale forcings (synoptic scale systems) and the RCM to account for sub-GCM grid scale forcings (e.g. local circulations, complex topographical features and land cover inhomogeneity).

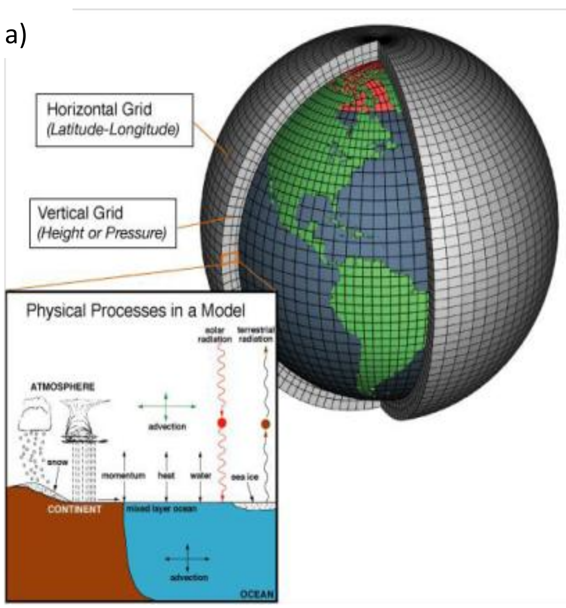


Figure source: http://celebrating200years.noaa.gov/breakthroughs/climate_model/modeling_schematic.html

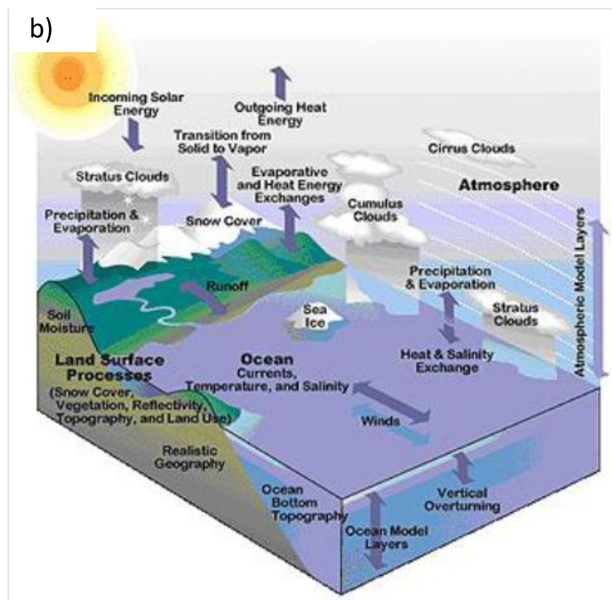


Figure source: http://www.ucar.edu/communications/CCSM/CLIMATE8.gif

Figure 11 (a) Typical horizontal and vertical resolution of a GCM. (b) Interactions and processes in an AGCM.

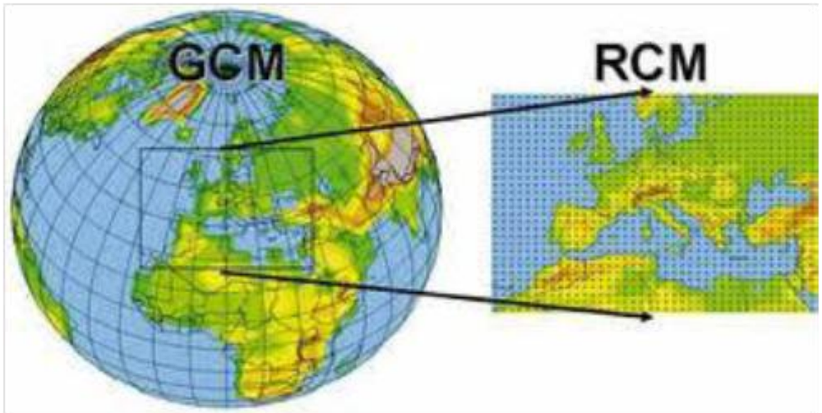


Figure source: https://secure.um.edu.mt/__data/assets/image/0012/124410/Model.jpg

Figure 12 Relative grid spacing of an RCM and a GCM.

Unit 2.3 Projections for the Caribbean

Key Ideas:

- **PRECIS is a regional model that has been run over the Caribbean.**
- **On the basis of the PRECIS project end-of-century projections have been generated for the Caribbean for some SRES scenarios.**
- **The end-of-century projections show an altered climate regime in the Caribbean.**
- **The end-of-century projections are useful for developing long term plans.**

Key Points:

PRECIS (Providing REgional Climates for Impacts Studies) is a PC-based regional climate model developed by the Hadley Centre of the Meteorological Office of the United Kingdom for use by non-Annex I Parties to the United Nations Framework Convention on Climate Change.

It is an atmospheric and land surface model of limited area and high resolution locatable over any part of the globe. It is based on the Hadley Centre's most up to date model: HadRM3P,and driven by the Hadley Center's GCM HadAMP3 using emission scenarios. The lateral boundary conditions are updated every six hours while surface boundary conditions are updated every day.

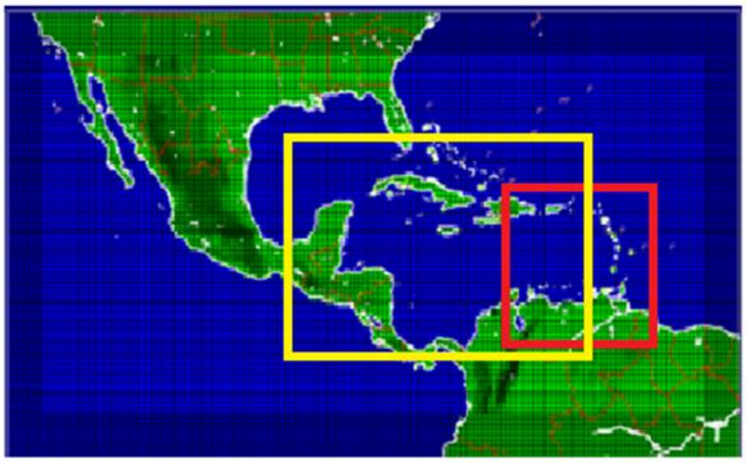
PRECIS has a regular latitude-longitude grid in the horizontal and a hybrid vertical coordinate. It has 9 vertical levels, the lowest at ~50m and the highest at 0.5 hPa. It has both 25 km and 50 km horizontal resolutions.

The PRECIS-Caribbean project saw the RCM run at 25 km over and eastern Caribbean domain and at 50 km over a wider domain covering all or part of the Caribbean, Central America, Florida, the northern territories of South America and sections of the Atlantic and Pacific oceans.

Simulations were done for both present day (1961-1990) and future (2071-2100) periods with the PRECIS RCM forced with output from the Hadley Centre GCM and the ECHAM-4 GCM. The PRECIS simulations were done for both a relatively high greenhouse gas emissions scenario (A2) and a relatively low emissions scenario (B2) to provide a range of projections.

By the end of the century, mean annual surface temperature is projected to change by 2.4°C (B2 scenario) – 3.6°C (A2 scenario) for the region as a whole. The corresponding projected increase in maximum temperature is 2.77°C (B2) and 3.72°C (A2). The region-wide warming is consistent with projections for other parts of the globe. It also far exceeds the historical variability of temperature within the region (about 2.5 degrees more).

There is an end of century drying pattern also evident from the GCM simulations for the Caribbean. Total annual rainfall under both the A2 and B2 scenarios will decline. Under the A2 scenario, mean annual rainfall in the main Caribbean basin (south of Jamaica and extending into Guyana) will reduce by 25-30%. With very few exceptions (see values for Haiti and the Dominican Republic) the countries of the Caribbean receive less rainfall by century's end under the more severe A2 scenario.



Taylor et al. (2007)

Figure 13 Caribbean Domains for PRECIS RCM simulations: Big or Blue Domain at 50 km (All Caribbean, Central America, southern USA and northern South America) and two smaller domains at 25 km -Yellow and Red Domains - Western & Eastern Caribbean.

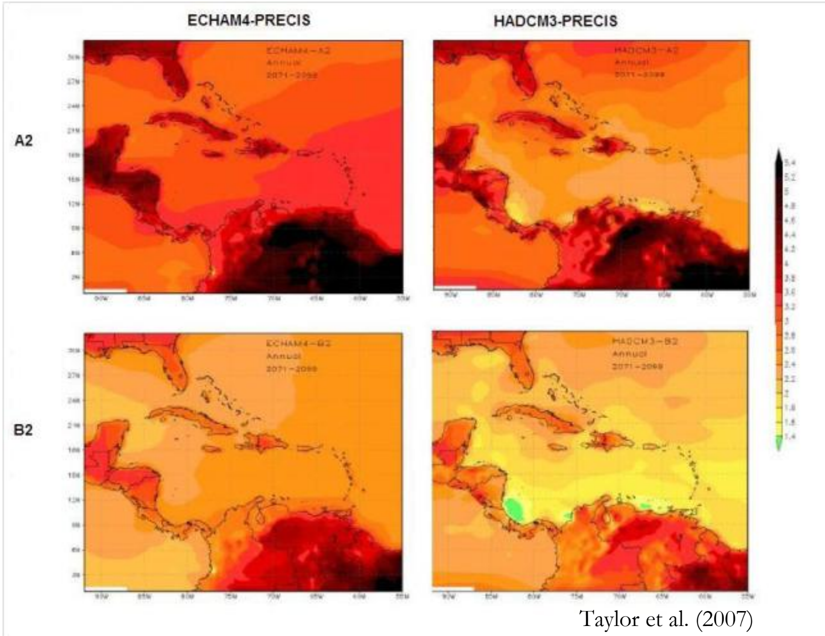


Figure 14a PRECIS projections of end-of-century temperature increase for the Caribbean region.

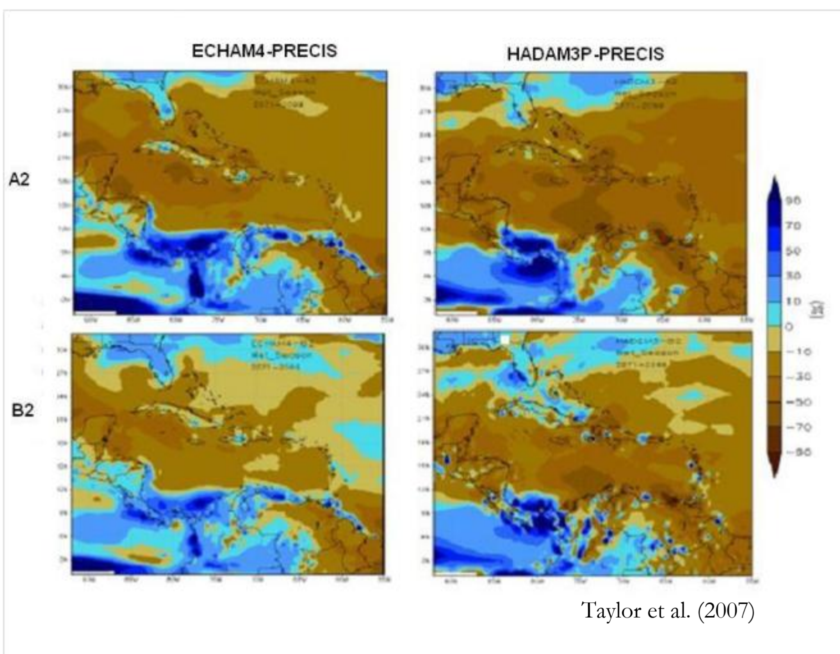


Figure 14b PRECIS projections of end-of-century percentage rainfall change for the Caribbean region.

Unit 2.4 Learning Exercise: Which Scenario?

Key Ideas:

- **Scenarios are associated with changes in socio-economic conditions.**

Exercise

Instructions

1. Candidates are to peruse the material provided on the IPCC Special Report on Emission Scenarios. Pay special attention to the Table. (Remember these are characteristics for the world as a whole and not specific to a single country).

2. Fill in Table 1 below using one of three options – up, down or stable (no change) based on the summary material. This will give you a good idea of the assumptions made by climate modellers when they choose scenarios to work with.

3. Now use your intuition (or your knowledge of your country's policy directions) to suggest what your country may be like in the year 2100 and fill in Table 2 below.

Questions

1. Do your projections match any of the scenario assumptions about the globe on the previous page?
2. Which scenario(s) would you to choose to model if you were a climate modeller?

Table 1

	Characteristics	2100s		
		UP	STABLE	DOWN
A2	Population Growth			
	GDP growth			
	Energy Use			
	Grassland			
	Farm / Arable Land			
	Resource Availability			
B2	Population Growth			
	GDP growth			
	Energy Use			
	Grassland			
	Farm / Arable Land			
	Resource Availability			
A1B	Population Growth			
	GDP growth			
	Energy Use			
	Grassland			
	Farm / Arable Land			
	Resource Availability			
B1	Population Growth			
	GDP growth			
	Energy Use			
	Grassland			
	Farm / Arable Land			
	Resource Availability			

Table 2

	Characteristics	2050's		
		UP	STABLE	DOWN
YOUR COUNTRY	Population Growth			
	GDP growth			
	Energy Use			
	Grassland			
	Farm / Arable Land			
	Resource Availability			

Scenario information

Summary Table showing the projected characteristic end of century changes associated with the respective SRES scenarios.

Scenario Group	A1			A2	B1	B2
	A1F1	A1B	A1T	A2	B1	B2
Population growth	low	low	low	high	low	medium
GDP growth	very high	very high	very high	medium	high	medium
Energy use	very high	very high	high	high	low	medium
Land- use changes	low-medium	low	low	medium/high	high	medium
Resource availability	high	medium	medium	low	low	medium
Pace and direction of technological	rapid	rapid	rapid	slow	medium	medium
change favouring	coal	balanced	non-fossils	regional	efficiency & dematerialization	dynamics as usual

Unit 2.5 Learning Exercise: Build your own future scenario

Key Ideas:

- **Given future change data from a model (GCM or RCM) one can build a scenario of future climate for location or country.**

Exercise

Baseline (Historical Data) **+** **Change** (Model Projection) **=** **Scenario** (Future Projection)

1. Each group will create future projections of mean temperature and cumulative rainfall for their country for a chosen time slice and a chosen scenario. The task will be done using the equation above.

2. Start with baseline climatologies of temperature and rainfall from monthly data provided earlier. Import into the given Excel spreadsheet.

3. Choose a time slice and scenario for future projections.

4. Now search the table of projections provided for the median model projected change for each season for the scenario and time slice you are analyzing. Fill in the Table below.

Season	**Temperature** *Change in °C*	**Precipitation** *% Change*
DJF		
MAM		
JJA		
SON		

5. Start with January. Add the projected changes from the table above for DJF to the baseline value for January. For temperature this addition will be the absolute value provided, whereas for rainfall the addition will be a percentage of the baseline. This gives (as in the equation above) the projected temperature or rainfall for January for that time slice. Repeat for the other months in the year to produce the projected climatology for the selected time slice.

6. In Excel plot the baseline and projected climatologies on one graph for temperature and another for rainfall.

7. Answer the following questions:

    a. How are temperature and rainfall projected to change as the century progresses?
    b. Will any time of year warm more than another?
    c. What likely impact (if any) will this have on your country?

Module 3

Modelling & Projections 2: Other Considerations

Module Summary

Aims and Learning Outcomes

This module aims at:

- Discussing other potential uses for model output including the analysis of tropical Atlantic climate phenomenon in the future.
- Discussing the limitations and uncertainties related to climate models.
- Discussing climate variability on shorter timescales.
- Explaining about seasonal climate predictions.
- Explaining what is meant by impact models.

At the end of the module the trainee will be familiar with:

- Other modeling research being done in the region.
- How this modelling research can feed into the demand for more information about climate impacts in the region, particularly in sectors.
- The rationale for ensemble modeling given the uncertainties and limitations associated with modeling.
- The mean seasonal variation of rainfall and temperature and some global phenomena which cause deviations from the mean.
- The usefulness of seasonal predictions.
- The link between climate models and impact models.

Module Flow

Unit 3.1	**Other Variables**	**The models produce a host of climate variables besides mean temperature and rainfall. What can these additional variables be used for? How are they helpful?**

Unit 3.2	**Limitations and Uncertainties**	**Notwithstanding their usefulness, models have inherent limitations and uncertainties associated with their output. What are these and how are these to be represented in the climate projections produced?**

Unit 3.3	Variability and Seasonal Prediction	Adapting to long term climate change can start with adapting to the variations in climate extremes currently being experienced. What is known about short term climate variability? Can it be predicted?

Unit 3.4	Impact Models	How can sectors use the output of climate models for gauging the impact of climate change?

Unit 3.5	Climate Alphabet Soup	A Learning Exercise related to Variability.

Unit 3.1 Other Variables

Key Ideas:

- **Models produce a lot of output variables i.e. not just rainfall and temperatures.**
- **Many of these variables can be used directly to generate future climate change scenarios.**
- **A large number of products and analyses can be made from the output variables or combinations of them.**
- **For the model post-processing process it is crucial to know from the users the number of variables desired and the time resolutions.**

Key Points

Most agree that models are currently the best way to predict climate change and they are constantly being improved. With the model outputs one can (i) obtain and use scenarios for climate change (ii) share the obtained results with all the scientific community, and stakeholders (iii) feed other numeric models (Hydrological, Crops models, etc).

Models produce a lot of data. Even though most time the variables analysed are mean temperature and rainfall, the models produce significantly much more variables than that. For example the standard diagnostic variables from PRECIS are shown in Figure 15.

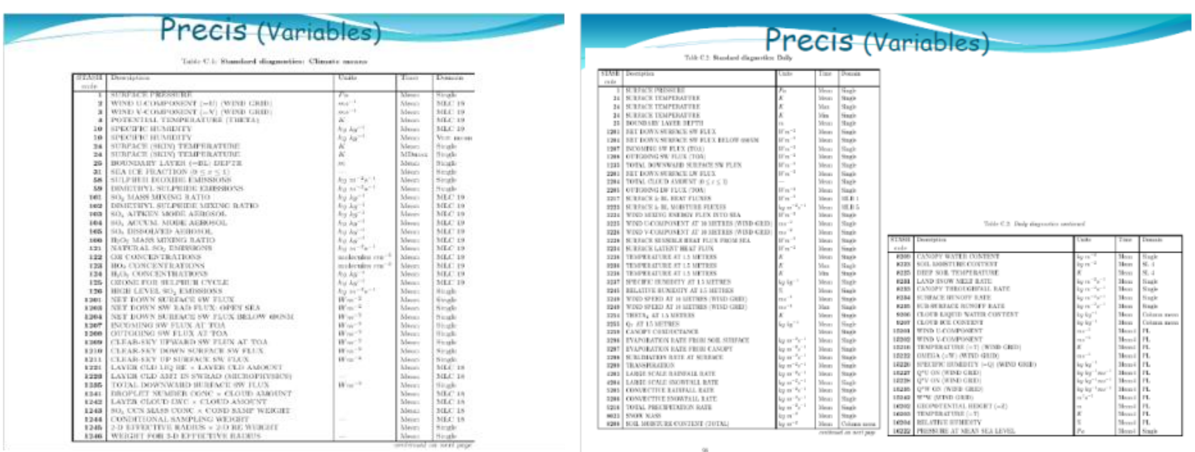


Figure 15 The number of diagnostic variables output by PRECIS.

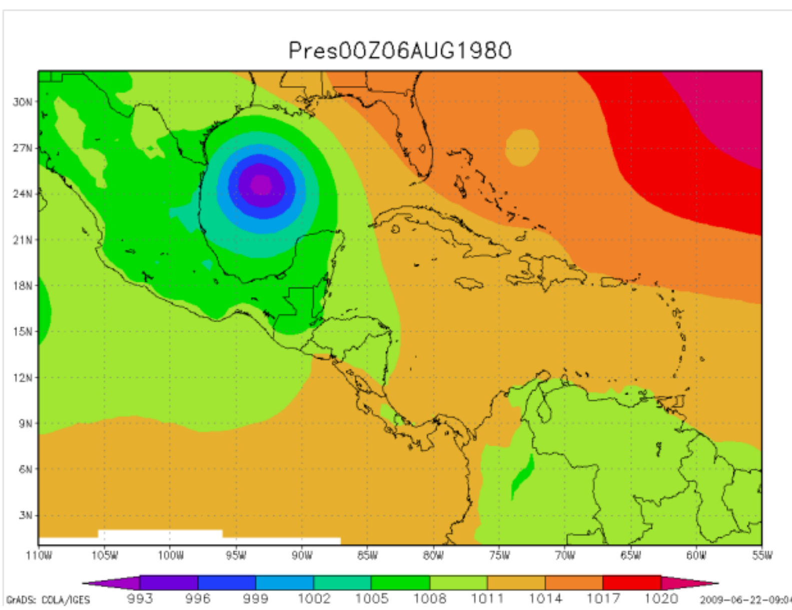
The number of variables allows for more detailed and advanced examinations of weather and climate features and how these will change in the future.

For example the regional model simulations currently being done in the Caribbean are allowing for an examination of:

1. **The Frequency of tropical cyclones in the Caribbean and Mexico**

The PRECIS model has shown a remarkable skill to recreate cyclonic vortices from information given by GCMs (see Figure 16). Despite big differences between A2 and B2, the SRES results do not show a notable difference in the number of days with tropical cyclone like vorticities. However, when PRECIS is forced by two different GCMs there is a big difference in the distribution of number of days with TC. There is also evidence that PRECIS simulations at 25 km resolution perform better with respect to tropical cyclone frequencies than 50 km resolution.

This kind of work is allowing the region to contribute to the debate about the impact of the projected increase in surface temperatures in Eastern Pacific near the coast of Mexico and the smaller projected increase in the Western Tropical Atlantic on tropical cyclones.



Taylor et al. (2007)

Figure 16 PRECIS simulation of Hurricane Allen, August 1980.

Cold fronts.

A cold front is defined as the leading edge of a cooler mass of air replacing (at ground level) a warmer mass of air. In our region it is the main contributor to rain in the non-rainy season.

Work is being done on an algorithm to identify cold fronts using outputs of a regional model like the RegCM. The method so far has proven effective in 92% of the cases when compare with the synoptic maps with ongoing work to improve the algorithm.

2. **Extreme Precipitation**

Extreme rainfall can have a severe impact on human life and livelihood and so policymakers and planners have an interest in determining how the frequency and intensity of extreme precipitation could change in the coming century. PRECIS can be used to generate detailed climate projections which will include extreme precipitation. To do so one has to establish whether PRECIS can realistically simulate detailed extreme precipitation. Work is currently being done with extreme rainfall indices, including:

- Wet day intensity - the multi-annual seasonal mean of precipitation on "rainy days". A "rainy day" (also called "wet day") is a day which there is more than 0.1mm of rain. This index allows for comparison of the total amount of rain which PRECIS produces in comparison to how much rain actually occurred (on "rainy days").
- Wet day frequency - the percentage of the total days in which precipitation occurs. This index allows for comparison between how often PRECIS produces precipitation vs. how often precipitation occurred in historical records.
- Extreme Precipitation – very very wet or dry days. This index allows for comparison of the times when PRECIS produces rainfall in the upper and lower 5% vs. the upper and lower 5% of historical observations (see Figure 17).

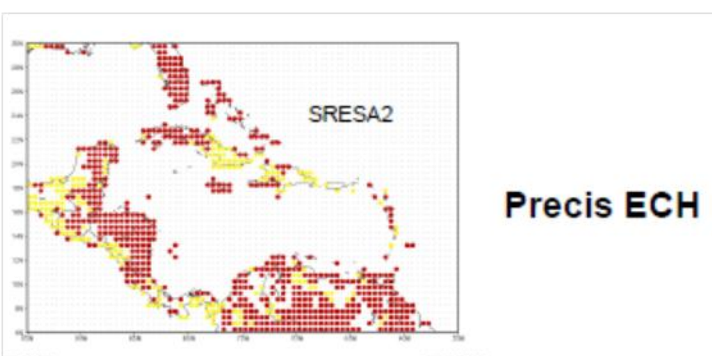


Figure 17 PRECIS simulation of zones of increasing drought through the end of the century.

Unit 3.2 Limitations and Uncertainties

Key Ideas:

- **Future climate projections ideally should come from an ensemble of model runs.**
- **The ensemble should include different models, different boundary conditions and different scenarios.**
- **In this way we account for uncertainties due to a number of factors.**

Key Points

Ideally future climates should come from an **ensemble** of model predictions. Doing so will result in a range of possible futures. Some notion of the range should be communicated when future scenarios are presented.

The ensemble should incorporate simulations of all (or as many as is possible) available scenarios (since each is equally plausible). There is unpredictability of natural and anthropogenic forcings i.e. it is impossible to predict solar activity, major volcanic eruptions or social/technological developments. There is also natural internal variability related to non-linear processes within the climate system. Because of the internal variability and non-linearity of the climate system and the random component of the external natural and anthropogenic forcings, many future climate states are possible, each with a likelihood of occurrence. Therefore, future climate change is characterized by an intrinsic level of uncertainty. Simulation of multiple future climates is important for reflecting this uncertainty.

One should also recognize that **models have a number of limitations** which include

- How they treat subgrid scale processes and the need for parameterizations (e. g. clouds).
- Resolution and computational resource. The need to discretize the system (spatially as well as temporally).
- Predictability limits associated with the non-linear system characteristic (chaos).
- Incomplete knowledge of the System function/limitations to incorporate all what we know.

There are, then, two kind of model uncertainties associated with (i) the different ways that different models are developed (ii) the different ways that physics parameters are represented in one model. This makes a case for also including different models in the ensemble as some models will perform some functions better than others.

The famous scientist Lorentz (1975) noted that in climate prediction there is predictability of the first and second kind. The former is an initial value problem i.e. prediction of the evolution of the climate system (or some of its components) given some knowledge of the initial state. The latter is a boundary value problem: Prediction of the response of the climate system (or some of its components) to external forcings. The ensemble should account for simulations with differing initial and boundary values.

The purpose of climate prediction is to reconstruct as closely as possible the PDF of possible future climates reflecting all the different uncertainty sources. Climate change prediction needs to be approached in a probabilistic way, using multiple models/ensembles.

Unit 3.3 Variability and Seasonal Prediction

Key Ideas:

- **Though long term climate change is important, there is still variability on shorter term timescales.**
- **The shorter term variability is driven by global climatic phenomenon such as ENSO, NASO, etc.**
- **If we can learn to live with the variability we now experience it is part of the strategy of adapting to long term climate change.**
- **Knowledge and prediction (where possible) of the shorter term variability is therefore important.**

Key Points

There is a seasonality to Caribbean climate.

For example, over most of the region the annual temperature range [difference in temperature between the warmest and the coldest month], is only about 2°C or 3°C, except over certain parts of Cuba where the range can be greater than 5°C. It peaks in July-August. Similarly for rainfall, there is a dry season early in year (January –April), a wet season (May –November). a bimodal pattern (dry period in July/August interrupts rainy season) and peak rain between September and November which coincides with peak hurricane activity.

As important as it is to understand climate change it is equally important to understand the dynamics that give rise to the seasonality as this is what life generally revolves around. Some of the key features giving rise to the seasonality are shown in Figure 18.

There are a number of global phenomenon which cause variations in the seasonal pattern by interrupting/altering one or more of the dynamical processes shown in Figure 18. They are in apart responsible for extremes in weather that happen each year. Two global phenomena which influence Caribbean climate are:

ENSO - El Niño-Southern Oscillation

- ENSO is a global coupled ocean-atmosphere phenomenon. During an El Niño (La Niña) there is an unusual warming (cooling) of the tropical Pacific Ocean. The Southern Oscillation is an accompanying fluctuation in the air pressure difference between Tahiti and Darwin, Australia. ENSO events prompt changes in weather patterns across the globe. They occur irregularly at approximately 3-6 year intervals. El Nino events are associated with a dry late wet season in the Caribbean and a wet early season during its year of decline.

NAO – North Atlantic Oscillation.

- This is a large scale seesaw in atmospheric mass between the subtropical high and the polar low. The NAO is the dominant mode of winter climate variability in the North Atlantic region ranging from central North America to Europe and much into Northern Asia. During its positive phase the Caribbean tends to be drier Caribbean (particularly the eastern Caribbean).

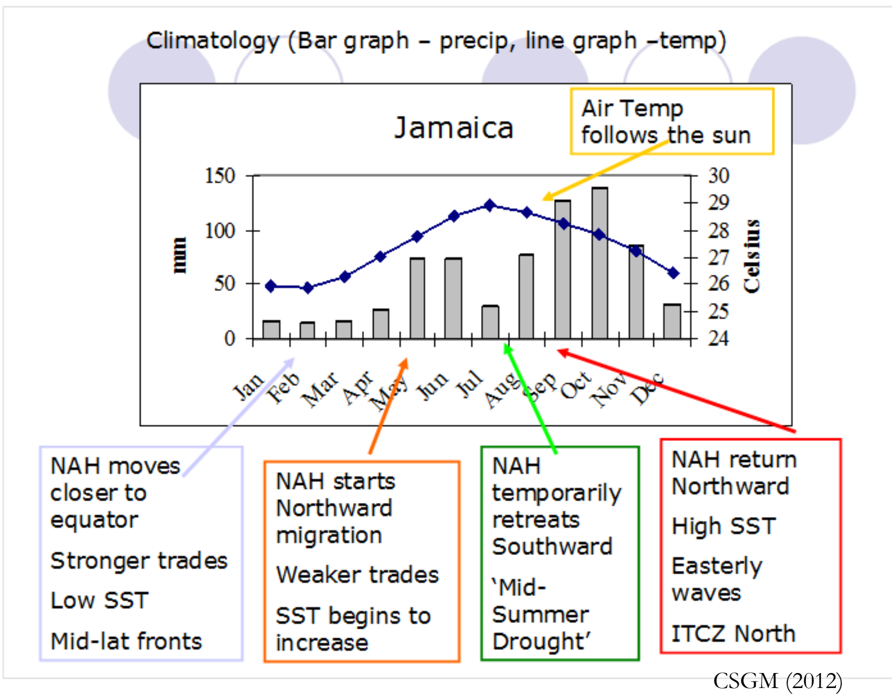


Figure 18 Rainfall (bar) and temperature (line) climatologies for Jamaica. Boxes track the changes in tropical Atlantic features which give rise to the rainfall climatology.

We can predict some of the variability of Caribbean climate if we know the evolution of the external forcing conditions e.g.

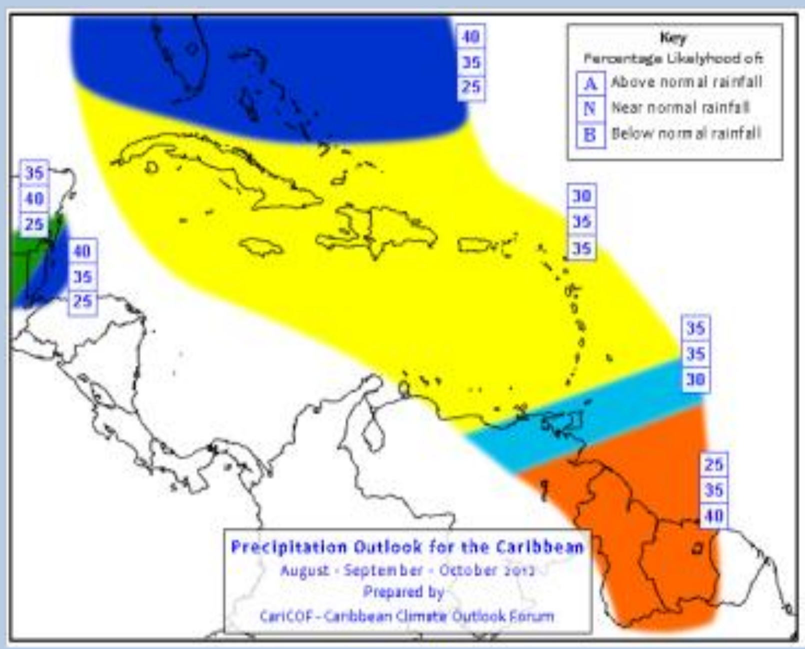
- evolution of Sea Surface temperature (SST)
- Interannual variability (like ENSO)
- Decadal variability (like NAO)

- Evolution of continental surface conditions
- Intraseasonal variability (notably soil moisture)
- Mutual influences

Many problems in seasonal climate prediction start by trying to establish some relationship (linear) between two sets of variables. An example would be to try and see whether the (SST) over any of the global oceans (variable one) is related to rainfall (variable two) at a certain given location of the globe. The knowledge of such a relationship would be useful in that the expected rainfall of the given location can be predicted if the SSTs of the global oceans are known in advance. The strength of the a relationship can be determined by computing the correlation coefficient.

A number of methods can be used to create prediction models including linear regression, discriminant analysis, neural networks, canonical correlation analysis.

A number of seasonal prediction efforts are underway in the region e.g. the Caribbean Climate Outlook Forum. The Caribbean Institute for Meteorology and Hydrology also puts out a seasonal rainfall forecast several times during the year (see Figure 19).



Rainfall in the Caribbean during August-September-October will likely become generally consistent with typical El Niño conditions. This means an increased likelihood of normal to above normal rainfall over the Bahamas, Belize and (possibly) some portions of the Greater Antilles whereas normal to below normal rainfall may occur in most parts of the Antilles and the Guianas, especially from the onset of the late rainy season in September.

Figure source: http://www.cimh.edu.bb/

Figure 19 Seasonal climate outlook for the Caribbean.

Unit 3.4 Impact Models

Key Ideas:

- **Climate change will negatively impact many different sectors and socioeconomic activities.**
- **Some sectors will be more impacted than others.**
- **Impact models help to quantify the impact of climate on a sector by incorporating them in a physical model.**
- **They can be useful for assessing future change as well as simulating the impact of an adaptation option.**
- **Sector assessments using validated impact models can be a very useful decision making tool.**

Key Points

Not all sectors that will be equally affected by climate change, since not all sectors are equally related to the magnitude and seasonality of climate variables.

Sectors that will be impacted by climate change include: **water resources, agriculture and food production in general, coastal and marine ecosystems, human settlements, human health, energy, and tourism**.

In order to estimate qualitatively/quantitatively what kind of impacts and what will be their magnitude on a given sector, we must have some conceptual or mathematical model relating values of climate variables with relevant sector parameters. This kind of tool is called an **impact model**. Even if it is not easy to explain, impacts models are driven by climate variables and its behavior in time.

Impact models can vary, in large part depending of the sector or the relevant sector parameters one is interested in.

For example, agricultural activities and models are related to many climate variables. In the agricultural sector, agriculture models are therefore used to model ecological and physiological processes inherent to plants, animals and ecosystems in general. Such processes are controlled not only by genetics but also by the abiotic environment, including physical conditions representing the day to day weather changes and daily values of climate variables. Agriculture models are among the more complex sector models. **No assessment is possible without adequate climate information.**

Some agricultural models are:

- WOFOST 7.1.2, CSM, DSSAT 4.5, Aqua Crop 3.1 Plus, which are crop models.
- JABOWA model simulating forests.
- SPUR 2.2 simulating cattle/pastures interactions.
- CENTURY 4.5 simulating biogeochemical cycles and organic matter decay in soils.

Past and actual values of climate variables are needed in order to run a sector impact model. This usually comes from historical climate datasets built by National Meteorological Services. Some complex and detailed impact models require daily datasets, (e.g. crop models) but others need only monthly mean data and even annual mean data.

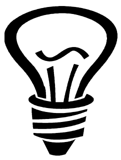
To assess future changes e.g. due to climate change**, expected values for the climate variables are also needed** for every relevant climate variable. They are obtained by creating climate change scenarios for any future date. This is the link between climate modelling and sector analysis. Even if future climate change scenarios may be constructed in different ways, most internally consistent scenarios are those based on **Global and Regional Climate Models runs**.

The structure of the necessary climate datasets is conditioned by the needs of the chosen impact model. The reverse is also true because the chosen impact model is conditioned by the nature of the available climate dataset. For example a minimum requirement of climate input data for a crop model consist of daily values of CO_2 atmospheric concentration, global solar radiation, maximum and minimum temperatures, precipitation, water vapor pressure and wind speed.

In making an impact assessment you need to first run your impact models with your **baseline climate data** i.e. the time series of climate variables actually observed in your meteorological stations network. Then you must run your impact models with **climate data generated from climate change scenarios.** Impacts from climate change are then derived by comparing impact model runs made with climate data projections for a future date with impact model runs made with values corresponding to the actual observed reference climate.

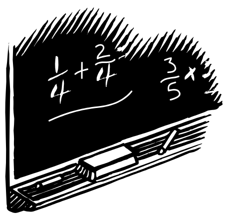
Adaptation options are then assessed the same way i.e. running the impact model but using climate data from the scenarios after including the modification you are proposing as an adaptation option. For example, modified input based on going from rainfed to irrigated agriculture, changing planting dates or any other adaptation option that is being assessed as a countermeasure to some detected negative impact of climate change.

Unit 3.5 Learning Exercise – Climate Alphabet Soup



Key Ideas:

- **Variability of local climate can many times be linked to (an acronymed) global phenomenon such as ENSO or NAO.**
- **The linkages between Caribbean climate and ENSO are explored.**



Teaching Tool

This unit will require some set up from before. Climate data brought by the participants or provided must be put in Excel for participants to access. They will also need access to the NINo3.4 dataset.

Climate Alphabet Soup

Caribbean climate is driven by a number of large scale systems spanning both the Atlantic and Pacific Oceans. These systems oscillate with periodicities of months or years, and help to determine the cyclical nature of the region's temperature and rainfall. The most well-known of these drivers is the El Niño-Southern Oscillation, which will be the focus of this exercise.

This exercise will examine two (2) simple ways of finding the relationship between your country's rainfall and El Niño. The Nino3 index is often used to capture SSTs over the pacific, and will be used for this exercise.

Open the ***Climate Alphabet Soup Worksheet*** provided. Data are presented as seasonal anomalies, which are deviations from the mean climate.

Correlation

The first way to find the relationship is via a correlation, which is a measure of dependence between two variables. Correlation values range from -1 to 1, where -1 represents a strong inverse relationship, 1 represents a strong direct relationship, and 0 indicates no relationship. For example, a value of 1 indicates that as Nino3 increases, so does rainfall.

To find the correlation, the function *correl* can be used. To use this function, type '=correl(time series 1, time series 2)', where rainfall would be highlighted as time series 1 and Nino3 as time series 2.

Linear Regression

Another method is to determine the equation of a model relating rainfall and Nino3. For this, we can do a linear regression using the function *slope*. To use this function, type '=slope(Y,X)', where Nino3 would be highlighted as X (the predictor) and rainfall as Y (the predictand).

The new model equation would then be (*slope* x *rainfall*) + *intercept*, where the function *intercept* calculates the point at which the graph crosses the y-axis.

Now make your own alphabet soup!

1. We will begin by copying your country's rainfall data from the ***Anomalies*** folder to the desktop. The data format now reflects seasons rather than months.
2. Paste observed seasonal data for your country for a 10 year period into the table labeled ***Exercise*** in the column Rainfall. Once that is done, copy Nino3 values from the sheet labeled ***nino3*** (in the same file) for the corresponding period and paste into the Nino3 column.
3. Below ***Exercise*** is a master table, in which the *correl*, *slope* and *intercept* functions have already been entered. This table examines the relationship between each season of Nino3 and each major rainfall season, namely MJJ (early wet), ASO (late wet) and NDJ (dry). Predictions will automatically be generated.
4. Plot your actual MJJ rainfall against the predicted rainfall of the Nino3 season with the strongest relationship.
5. Repeat with ASO and NDJ rainfall and corresponding Nino3 predictions.
6. Answer the following questions:
    a. Is there any influence of Nino3 on your country's rainfall throughout the year? When is it strongest?
    b. How can knowledge of a climatic relationship help in local forecasting of climate variables?
    c. Give one comment on each of your three (3) graphs. Would you trust any of your models?

Module 4

Related Issues

Module Summary

Aims and Learning Outcomes

This module aims at:

- Discussing ongoing modelling efforts in the Caribbean.
- Discussing the difficulties with communicating climate change.
- Pointing to ways in which climate change communication can be more effective.
- Providing participants with an idea of who the Caribbean Community Climate Change Centre is and what they do.
- Discussing what costs are associated with climate change.

At the end of the module the trainee will be familiar with:

- The major modelling centres in the Caribbean region.
- The mandate of the Caribbean Community Climate Change Centre.
- Efforts being undertaken to communicate climate change in the Caribbean.
- Adaptation projects ongoing in the region and what makes them cost effective.

Module Flow

Unit 4.1	**The Caribbean Modelling Initiative**	**What efforts are currently underway to generate new modelling data? Who are the major players involved in modelling and what is the modelling plan being pursued?**

↓

Unit 4.2	**Communicating Climate Change**	**After the maps are generated from the model, how does one convey the meaning to the general public, decision makers, communities, or to anybody who needs it. What are the obstacles to communicating climate change science?**

↓

Unit 4.3	The Cost of Climate Change	What is climate change costing the Caribbean region? Where do these costs lie? Are they only associated with Impacts or are there costs associated with building resilience?

Unit 4.4	Climate Change Institutions	The who, what, and why about the Caribbean Community Climate Change Centre.

Unit 4.1 The Caribbean Modelling Initiative

Key Ideas:

- **There is an articulated Modelling Framework to generate new climate data for the Caribbean region.**
- **The Caribbean Modelling Initiative is a collaborative effort by six Caribbean agencies which provide data and modelling services.**

Key Points

In the last decade, significant initial steps have been taken to increase the region's resilience to climate change through the provision of climate information at the scale of the Caribbean region. These include the emergence of a Caribbean Modellers Group and a regionally defined modelling agenda.

The Caribbean Modellers Group is a consortium of regional institutions pooling efforts to provide downscaled climate change science for the Caribbean from within the Caribbean. Through shared experience and effort, the capacity to answer climate change questions and provide climate change information at the scale of the Caribbean islands has dramatically increased. The initial science results of the Caribbean Modeller's Group (utilising the PRECIS regional model) have formed the basis for many of the reports and studies related to Caribbean climate change which have appeared in the last few years.

The Caribbean Modelling Initiative (CMI) facilitates the entrenchment and expansion of the work of the modellers group through the pursuit of a regionally articulated modelling agenda.

The CMI will build on the successes of the Caribbean Modellers Group by recognizing the value of regional and international collaboration so that prompt results can be generated and duly disseminated. This will *inter alia,* enable effective adaptation to climate change and present an integrated and holistic approach to addressing the leading challenge of the 21st Century.

The CMI will facilitate the pursuit of the three science objectives below.

- <u>Objective 1:</u> To fully utilize data already available as output from the PRECIS model and to do further assessment of the value added by using regional climate models in the Caribbean.
- <u>Objective 2:</u> To increase the range of analyses performed including the examination of extreme events and hurricanes. To increase the number of additional climate variables analysed in order to increase the variety of impact/sectoral studies that can be successfully conducted.

- Objective 3: To provide new and additional climate change projections of scale that are harmonized with other regional projections of the Fifth Assessment Report (AR5) of the IPCC. This will be done through the use of new climate change scenarios and simulations using other regional models. To undertake comparison and validation studies. To quantify uncertainties and provide a range of model results for use in regional adaptation strategies to climate change and provide effective data delivery for end-users.

The CMI is a collaborative endeavour between six regionally based agencies. These are namely the Caribbean Community Climate Change Centre (CCCCC), the Caribbean Institute for Meteorology and Hydrology (CIMH), the University of the West Indies, Cave Hill (UWI CHill), the University of the West Indies Mona, through the Climate Studies Group, Mona (CSGM), the Instituto de Meteorología de la Republica de Cuba (INSMET), and the Antom de Kom University of Suriname (AdeKUS). Additionally, there has been technical support from the Hadley Centre.

Unit 4.2 Communicating Climate Change

Key Ideas:

- **Challenges exist in communicating climate change as it is seen as a complex and difficult scientific issue.**
- **Notwithstanding, communication of the issue especially in the Caribbean has gotten better in the recent past due to organizations like PANOS Caribbean.**
- **Media are playing a significant part in the increased communication effort but there needs to be more strategic interventions and capacity building.**
- **Alternative and social media can be very effective to fill the gaps that traditional media does not cater to.**

Key Points

Part of the **challenge** of communicating climate change science **is the perceptions that exist** about it. The challenges sorround (i) the fact that climate change is a difficult issue to communicate because of technical jargon filled nature of the subject (ii) there is still debate about the 'credibility of climate change' (iii) climate change is still to a large extent an 'academic and scientific' issue not yet a public issue.

A study by Oxford University's Reuters Institute for the Study of Journalism analysed the coverage given to the UN's Copenhagen summit on climate change in 2009. It found that the media in the studied countries tended to 'underreport' climate science during the summit. Nearly 80 per cent of the articles mentioned the science in less than 10 per cent of their column space.

2005 KAP study done by the Jamaica Meteorological Office showed a general feeling of complacency and indifference towards climate change and its effects; strong to moderate interest in climate change; and that many persons think that the Government should play a stronger role in addressing the impacts of climate change on communities.

Journalists themselves (Jamaican context) suggest that (i) the level of coverage of climate change issues in the local and national media is low as issues such as crime, poverty and violence are given higher priority (ii) there is a lack of resources to cover the issue, and (iii) the coverage given has little impact as even if the quality is reasonable there is no impact because of the lack of quantity.

In the Caribbean the challenge to communication include: (i) no systematic dissemination hub in the region for climate change info (ii) huge gaps between scientists, academics, policymakers and 'regular' publics (iii) vulnerable sectors identified in national climate change and regional strategies still need to be properly sensitised on climate implications for them as well as mobilized (iv) limited political buy in i.e. the political will to act on climate change still needs work.

PANOS Caribbean is a regional non-government organisation that uses information for development. PANOS works with media to communicate for sustainable development. They are based in Haiti with offices in Jamaica and Washington. They use multiple strategies for communicating climate change including (i) popular personalities as champions of climate change (ii) producing media packages including a theme song and music video, min-ialbum of climate and environmental songs available for general use (iii) school tours and community meetings (iv) high visibility projects e.g. tree or mangrove replanting (v) vulnerable sectoral workshops (vi) consistent media coverage and policy intervention (vi) piloting a national Communication strategy for climate change.

Key to PANOS success has been (i) **Building of multi-sector partnerships (ii) promoting behaviour change among highly visible 'champions of climate change' (iii) sectoral sensitization and dialogue (iv) working on communication policy impact.**

Some recommendations for better communication:

- The schools are ideal for starting this process of awareness and responsible environmental usage and thus should be used more for climate change education.
- The programme of public awareness on climate change may be launched as a stand alone programme in the first place but be institutionalized into an overall environmental awareness
- A Caribbean image bank should be incorporated into websites that enables journalists to download and use images in stories on climate change.
- Policy makers should invest in public media initiatives that will provide space and resources for journalists who want to cover key environmental issues.
- All stakeholders need to engage the interest of journalists.
- There should be constant interaction between the people who have the information, the media and those affected.
- Policy makers should make available financial resources for capacity-building programmes for journalists.
- The media must see a role for themselves in engaging in climate change debates and should be encouraged to do so.
- There should be more (re-)engagement by climate scientists with journalists to explain where there is scientific consensus and where there is not.
- There should be more dedicated climate change press officers at universities and research centres
- More imaginative use of new media is needed.
- Less adversarial coverage of climate science, but more frontline reporting on what people are experiencing and what they are doing about it.

Unit 4.3 The Cost of Climate Change

Key Ideas:

- **Climate change impacts are already costing the costing the Caribbean region and will likely continue to prove an economic challenge to Caribbean countries given the projections.**
- **Some sectors will be affected more than others.**
- **Adaptation can offset some of the anticipated costs, but adaptation itself comes at a price.**
- **Long term adaptation projects must be carefully considered in terms of the cost benefit they will accrue.**

Key Points

The CARICOM Community Climate Change Centre (5 C's) estimates that climate risks are already costing the region between 4% and 6% of GDP annually. This is **comparable in scale to serious economic recession**.

They also suggest that annual projected climate change impacts will range between 8% and 15% under a Business as Usual scenario (BAU) by 2050 (between US$5.5 billion to US$9 billion annually at 2008 prices*)*.

The sectors hardest hit will be **tourism** and **agriculture**.

Much of the damage from climate change tends to be exacerbated by poor planning and poverty.

Some countries can avoid nearly 80% of damage by implementing cost-effective adaptation measures. However, adaptation is expensive and will require additional funding of between US$3 – US$5.2 billion annually by 2030 under BAU (estimate from the 5 C's). One should therefore not rush into making long-lived investments in adaptation unless these are robust to a wide range of climate outcomes or until the range of uncertainty about future weather variability and climate has narrowed.

The better option may be to **start with low-regret options.** Adaptation to climate change should start with the adoption of measures that tackle the weather risks that countries already face, for example, more investment in water storage in drought-prone basins or protection against storms and flooding in coastal zones and/or urban areas. Climate change will exacerbate these risks. At the same time one should beware of creating incentives that encourage development in locations exposed to severe weather risks.

Hard and soft approaches to adaptation are two sides of the same coin. Good policies, planning, and institutions are essential to ensure that more capital-intensive measures are used in the right circumstances and yield the expected benefits.

Countries must calculate an adaptation business case before proceeding with a project, including an investment plan. A **Cost Benefit Framework in Assessing Adaptation Pilots would include:**

- Examined adaptation objectives (*must be quantifiable*)
- Reviewed baseline (*the situation without the adaptation intervention*)
- Quantified and aggregated costs over specific time periods (*direct and indirect – social welfare losses and transitional costs*)
- Quantified and aggregated benefits over specific time periods (*market values, avoided losses, contingent valuation*)
- Calculated net benefits

Some good adaptation options include improved building codes and enforcement of such codes; mangrove reforestation; early warning systems; salt water reverse osmosis using renewable energy sources; land use planning; catastrophe insurance.

Some examples of adaptation projects in the Caribbean are shown in Table 6 below.

Economic development is a central element of adaptation to climate change, but it should not be business as usual.

The cost of climate change is also the cost of investing in better data management and early warning systems, enforcing building codes, investing in human capital, developing competent and flexible institutions, and tackling the root causes of poverty.

Table 6 Some Caribbean Adaptation projects

Saltwater Reverse Osmosis System - Bequia	Coconut Bay Resort – Greywater Recycling – St. Lucia	Retrofitting the Marchand Community Centre – St. Lucia	Revised Management Plans for Morne Trois Pitons & Diablotin National Parks - Commonwealth of Dominica
			
• 300 households using 10,000 gallons of water per day • Total Investment of US$993,162 (*SWRO and PV system*) • Life span - 20 year (to 2030) • Net Present Value (*financial analysis*) • (US$1.23 Mn) – (US$0.22 Mn) • Net Present Value (*economic analysis*) • US$0.68 Mn – US$0.80 Mn	• Investment cost (US$439,760) [*Construction of Rainwater Harvesting and Wastewater Recycling Facility*] • Rainwater harvested (*4.1 million litres annually*) • Water recycled (*at least 60% re-charging aquifers*) • 20 year (to 2030) • Net Present Value (*financial analysis*) (US$0.34 Mn) – (US$0.25 Mn) • Net Present Value (*economic analysis*) US$0.04 Mn – US$0.13 Mn	• Total Investment cost (US$786,269) • Lifespan of 20 years • Water consumption of 300,000 gallons annually • Rain water harvesting and water storage capabilities • Water conservation technologies • Photovoltaic\solar panels technology • Food and emergency items storage • Net Present Value (*economic analysis*) US$0.45Mn – US$1.32Mn	• Investment Costs = US$125,500 • Draft Plans for Buffer zones around the parks to improve sustainability • Conduct Met Data Collection needs assessment, and develop a Data Collection and Management Strategy for Dominica's National Parks Management. • "Data Scraping" Exercise to collate, Dominica's Environmental reports, and enter documents into a database that is linked to the Centre's Clearing House.

Unit 4.4 Institutions of Climate Change

Key Ideas:

- **The Caribbean Community Climate change Centre also known as the 5 C's is a primary Institution of Climate Change within the region.**
- **The 5 C's is a regional institution with a mandate to explore climate change issues.**
- **The 5 C's has developed a regional implementation plan for mainstreaming climate change into regional government policies and actions.**
- **The 5C's works through regional and international partnerships.**

Key Points

The Caribbean Community Climate Change Centre (5 C's) is a CARICOM Specialized Institution with the Mandate to coordinate the regional response to climate change and manage efforts to adapt to its projected impacts. The Heads of Government of CARICOM at their annual meeting in July 2002 endorsed the creation of a permanent capacity in the region to address climate change issues. And the Centre became operational in January 2004. The Centre is registered under the UN System as a CARICOM Specialized Agency:

The Centre is:

- The key node for information on climate change issues and on the CARICOM member states' response to managing and adapting to climate change
- A repository and clearinghouse for regional climate change information and data, and provides climate change-related policy advice and guidelines to the CARICOM states through the CARICOM Secretariat.
- Recognized by the United Nations Framework Convention on Climate Change (UNFCCC) as the focal point for climate change issues in the Caribbean.

To achieve its operational goals the Centre collaborates with other institutions.

The CARICOM Heads of Government in October 2007 mandated the 5Cs to prepare a Regional Framework for Achieving Development Resilient to Climate Change. The Framework was completed, and endorsed by Heads in July 2009 who further requested the development of an Implementation Plan (IP). The IP was approved by the Heads of Government on 9 March, 2012.

The Strategy identified main areas for involvement and effort:

- Mainstreaming climate change into the sustainable development agenda and work programmes of public and private institutions in all Caribbean Community countries at all levels.
- Promoting systems and actions to reduce the vulnerability of Caribbean Community countries to global climate change wherever possible.
- Promoting measures to derive benefit from the prudent management of forests, wetlands, and the natural environment in general, and to protect that natural environment.
- Promoting actions and arrangements to reduce greenhouse gas emissions, including those aimed at energy-use efficiency by increasingly resorting to low-emission renewable energy sources.
- Encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate (e.g. see Figure 20).

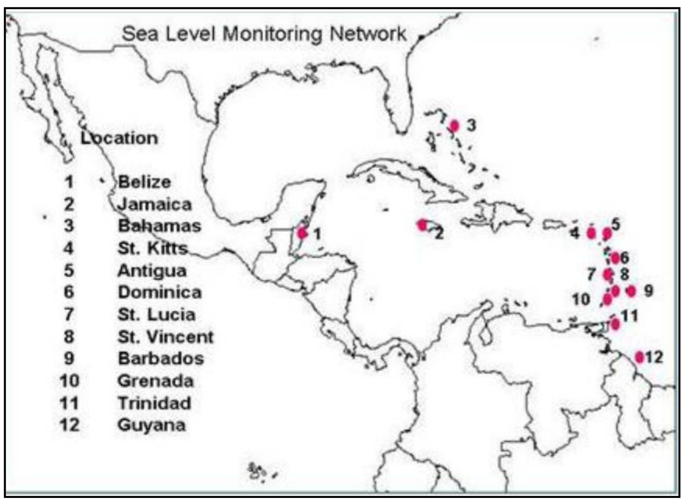


Figure 20 Example of work being undertaken by the 5C's. The expansion of meteorological and hydrological monitoring networks throughout the region. 106 additional hydrometeorological stations are being installed throughout the region including Cuba, Dominican Republic, Haiti and Suriname.

Specific priority actions identified by the IP

- Develop and implement a risk management approach to decision making.
- Develop sector specific adaptation policies at the national level.
- Strengthen national and regional climate change negotiating skills.
- Implement the 'three-ones' principle to embed a coordinated approach to climate change security across governments i.e. One coordinating mechanism; One Plan; One monitoring and evaluation framework.
- Actions to de-risk the Caribbean to improve the opportunities for private sector investment.
- Review CARICOM regional policies, regional organisation policies and National policies and identify specific actions to deliver convergence with the Regional Framework and IP.

Module 5

Optional Units

Module Summary

Aims and Learning Outcomes

This module aims at:

- Discussing vulnerability to climate and the terms associated with defining such vulnerability.
- Discussing the role of Integrated Assessments and Integrated Assessment Modelling in examining vulnerability and adaptation.
- Discussing what is meant by Adaptation.
- Articulating what is being done in the region with respect to adaptation.
- Introducing the concept of mitigation.

At the end of the module the trainee will be familiar with:

- The concept and definition of Vulnerability.
- The concept and definition of Integrated Assessments.
- Types of Integrated Assessment Models.
- The concept and definitions of Adaptation and Adaptive Capacity.
- The role of climate science in the adaptation process.
- What is mitigation and some mitigative strategies that could be employed by the region

Module Flow

Unit 5.1	**Vulnerability**	**Climate change is a serious issue for the Caribbean because of how vulnerable it is to weather related hazards. What is meant by vulnerability and how is it related to other key terms like adaptation and resilience?**

Unit 5.2	**Integrated Assessments**	**There are useful methodologies and tools out there for communities or countries that can generate information for decision making taking into account climate change modelling output. One such methodology is an Integrated Assessment and one such tool is Integrated Assessment Modelling.**

Unit 5.3	**Regional Adaptation**	**Adaptation is a necessary strategy for the Caribbean given how vulnerable the region currently is to climate hazards and that the vulnerability will increase under climate change. What then is the region doing about the need to adapt?**

Unit 5.4	**Mitigation**	**Mitigation is the 'other action' that can be taken when it comes to climate change. What is it and what can the region do about it?**

Unit 5.1 Vulnerability

Key Ideas:

- **Vulnerability is a function of exposure, sensitivity, potential impact and adaptive capacity.**
- **In the disaster management community: Resilience = adaptive capacity.**
- **Decreased vulnerability does not indicate increased resilience.**

Key Points:

Vulnerability can be defined in a number of ways:

- IPCC SAR - the extent to which climate change may damage or harm a system. It depends not only on a systems sensitivity but also on its ability to adapt to new climatic conditions.
- Sustainable Science - the degree to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation of stress/stressor.
- Climate Scientist - the likelihood of occurrence and impacts of weather and climate related events.
- International Strategy for Disaster Reduction (ISDR) - The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

Vulnerability is a function of exposure, sensitivity, potential impact and adaptive capacity (see Figure 21).

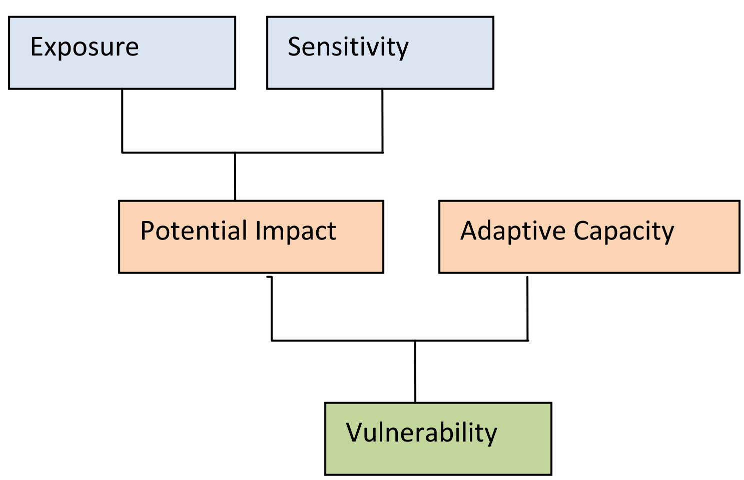


Figure 21 Vulnerability Schematic

From the above it can be seen that there are some key terms linked to Vulnerability. As defined by the International Strategy for Disaster Reduction (ISDR) Handbook, they include:

- **Adaptation** – the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
- **Coping capacity** - the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.
- **Hazard** - A dangerous phenomenon, substance, or condition that may cause loss of life, injury, property damage, loss of livelihoods and services, social/economic disruption, or environmental damage.
- **Resilience** – the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
- **Risk** - The combination of the probability of an event and its negative consequences.

Factors that affect vulnerability include (i) Physical - physical impact on the built environment or infrastructure and population (ii) Social – refers to the well being of the individual and to the communities (iii) Economic loss – classified into 2 categories i.e. loss which is tangible and intangible. Each category is further subdivided into direct and indirect loss.

Types of Vulnerability include (i) **Biophysical vulnerability** – a function of the character, magnitude, frequency, sensitivity, and adaptive capacity of a system to the hazard to which is exposed, and (ii) **Social vulnerability** – the extent to which a system is susceptible to damages

Measurement of vulnerability is via a **Vulnerability Assessment**. Measurement is often referred to as in index and there are three basic methods for computing a vulnerability index – (i) Normalization procedure (ii) Mapping on a categorical scale (iii) Regression method. Some types of Vulnerability Assessment include Community Vulnerability Assessment (CVA), Hazard Vulnerability Assessment (HVA), and Climate Vulnerability and Capacity Analysis (CVCA).

Resilience is needed to combat vulnerability.

Things that need to resilient include:

- Infrastructure – Roads, Bridges,
- Critical Facilities- Hospitals, Fire Stations, etc.
- Lifeline Systems – Health, Water, Power
- Housing
- DRM System
- National Security Systems
- Education Systems

Resilience must be built into **Development**

Resilience should be achieved through development which addresses technical issues, organizational issues, socio-economic aspects and the environment (see Table 7 below).

Table 7 Building Resilience

Technical	Organizational	Socio-Economic	People
Risk analysis, mapping should inform – Location – Design of structures – Type of infrastructure Critical facilities, infrastructure must be designed with an additional factor of safety • Redundancy – alternative/duplicate • Maintenance - structures must be properly maintained	Resilient Emergency Management systems • Evacuation routes remain open • Emergency telecommunications must remain functional • Emergency Operational Centres must survive or be up within hours • Shelters should be safe, equipped	Diversified, vibrant economy • Robust private and public sector • Risk Transfer	Adequate income to afford safe housing • "Cushion" – insurance/savings/family • Knowledge and skills to make their communities resistant

Unit 5.2 Integrated Assessments

Key Ideas:

- **Integrated Assessments are a tool for understanding complex environmental problems which hopefully lead to more informed decision-making.**
- **There are different types of Integrated Assessment Models (IAMs).**
- **Integrated Assessments support Vulnerability & Adaptation research as impact assessment modelers study the range of human activities & the intersection of human & natural systems.**

Key Points:

An **Integrated Assessment** is a framework for combining knowledge from a range of disciplines when conducting an Assessment.

Integrated Assessments are useful for (i) coordinated exploration of possible future trajectories of human & natural systems; (ii) development of insights into key questions of policy formulation; (iii) Prioritization of research needs in order to enhance the ability to identify robust policy options. They therefore give a broader set of information, serve as a tool for understanding complex environmental Problems and (hopefully) lead to more informed decision-making.

Key features of **Integrated Climate Change Assessments** are that they consider the social & economic factors that drive the emission of greenhouse gases, the biogeochemical cycles & atmospheric chemistry that determines the fate of those emissions, and the resultant effect of greenhouse gas emissions on climate and human welfare.

Integrated Assessment Modelling (IAM) is a tool for conducting an Integrated Assessment. It has the ability to calculate the consequences of different assumptions & to interrelate many factors simultaneously. Its primary constraint is the quality and character of the assumptions and data that underlie the model.

Major Classes of IAMs are shown in the Table 8 below as well as the relative advantages and disadvantages. There are over 20 twenty climate change IAMs examining economic issues, physical models, global focus, regional focus, etc. The best one to be used is the one that answers the questions you need answered and/or fulfills the task you need done!

General guidelines for using IAMs include using one that:

- Most closely addresses the question
- Produces results at the spatial scale that is most appropriate for the task
- Is most appropriate for addressing the key sectors targeted.

- Is appropriate for the target audience
- Is well documented with explicit assumptions
- Uncertainties are specified in model inputs and reflected in model outputs
- Has been exposed to careful peer review
- Is not so complex that it cannot be understood
- Has been developed by a team of experts with the background and expertise appropriate for addressing the question

Table 8 Characteristics of Integrated Assessment Models.

Major Classes of IAMs	Advantages of IAM	Disadvantages of IAM
Policy Optimization Optimize key policy control variables such as carbon emissions control rates or carbon taxes, given formulated policy goals. 1) Cost-benefit models, which attempt to balance the cost & benefits of climate change policies. 2) Target-based models, which optimize responses, given targets for emission or climate change impacts. 3) Uncertainty-based models, which deal with decision making under conditions of uncertainty. **Policy Evaluation** Policy evaluation models project the physical, ecological, economic, & social consequences of specific policies. 1) Deterministic projection models, in which each input & output takes place on a single value. 2) Stochastic projection models, in which at least some inputs & outputs are treated stochastically. Policy Evaluation IAMs have helped identify critical knowledge gaps in several areas. e.g. the balancing of the carbon cycle, integrated land-use analysis, & sulphur aerosols.	1. Allow the setting up of simulations based on scenarios for the future. 2. Incorporate mechanisms governing the complex link between economy & environment. 3. Can deal with uncertainty about the future evolution of economic & environmental parameters. 4. Can be used to isolate the effects of a particular parameter on other mechanisms governing economic & environmental processes. 5. Provide a large amount of information about the path of significant policy variables over time.	1. Do not provide forecasts, but only simulations and as such can only provide 'hypothetical data'. 2. Sometimes offer contrasting results depending on different assumptions. 3. Implementation of IAMs & their use can be time consuming for practitioners, & research centres therefore tend to use their own models. 4. IAM codes are not always available for the scientific community & results may at times appear quite cryptic. 5. Trade-off between complexity of models & comprehension of results.

Integrated Assessments support Vulnerability & Adaptation research as impact assessment modelers study the range of human activities & the intersection of human & natural systems.

Collaboration among climate modelers, experts on technological innovation & diffusion, & experts in impacts, adaptation and vulnerability will provide important new insights to those who are wrestling with simultaneous mitigation and adaptation decisions. More sophisticated merging of IAMs with other climate research models will yield new scientific insights into the magnitude and dynamics of human decisions on both the Earth system & on other human systems.

Unit 5.3 Regional Adaptation

Key Ideas:

- **The Caribbean region is very vulnerable to climate change.**
- **Enhanced adaptive capacity would reduce vulnerability.**
- **CARICOM has recognized the need for enhanced adaptive capacity and has a strategy for addressing it as well as a series of activities doing so in various sectors.**
- **There are some science needs which if addressed can enhance the adaptive capacity of the entire region.**

Key Points:

Adaptation to climate change can be defined as adjustments of a system to reduce vulnerability and to increase its resilience to climate change. Adaptation can either occur in anticipation of change (anticipatory adaptation) or be a response to those changes (reactive adaptation).

Enhanced adaptive capacity would reduce vulnerability to climate change. Generally activities for achieving enhanced adaptive capacity include: (i) improving access to resources (ii) reducing poverty (iii) lowering inequities of resources and wealth among groups (iv) improving education and information (v) improving infrastructure (vi) improving institutional capacity and efficiency.

The CARICOM perspective is that CARICOM countries' contribution to global GHG emissions budget negligible. Yet they are particularly vulnerable to impacts of climate change particularly since the region is already vulnerable to present day risks from climate variability. It is incumbent on region to build capacity to adapt to climate change.

CARICOM's perspective is articulated in the **LILLIENDALL DECLARATION.**

- Adaptation and capacity building must be prioritised and a formal and well financed framework established within and outside of the Convention, including the multi-window insurance facility, to address the immediate and urgent, as well as long term, adaptation needs of vulnerable countries, particularly the SIDS and the LDCs;
- The need for financial support to SIDS to enhance their capacities to respond to the challenges brought on by climate change and to access the technologies that will be required to undertake needed mitigation actions and to adapt to the adverse impacts of climate change.

It is also articulated in the **REGIONAL STRATEGIC FRAMEWORK.** This framework is comprised of five key strategies and associated goals designed to significantly increase the resilience of the CARICOM economies. Three of these (goals 1,3,&4) address Adaptation.

- Mainstreaming climate change adaptation strategies into the sustainable development agendas of CARICOM states.
- Encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate.
- Promote the implementation of specific adaptation measures to address key vulnerabilities in the region

CARICOM Member States have had **programmes** since the late nineties addressing adaptation to Climate Change.

- 1997 – 2001: Initiated Adaptation Planning through the GEF-sponsored project CPACC (Caribbean Planning for Adaptation to Climate Change)
- 2001 – 2004: Adaptation Planning continued under the CIDA-sponsored project, ACCC (Adapting to Climate Change in the Caribbean)
- 2004 – 2008: Mainstreaming the adaptation plans initiated under the GEF-supported project, MACC (Mainstreaming Adaptation to Climate Change)
- 2007-2010: The GEF-sponsored SPACC project which supports efforts by three island states (Dominica, Saint Lucia and Saint Vincent and the Grenadines) to implement specific pilot adaptation measures.

CARICOM's approach is downscaling → regional climate change projections → regional climate change scenarios → + impact models (crop, hydrology models) → impacts of extreme events under different climate scenarios → Climate impact scenarios → Adaptation options (Includes cost benefit analyses of different options).

There are currently a suite of activities underway in CARICOM to:

- Determine the extent of risk arising from climate change to which region will be exposed in future.
- Determine the vulnerability of the region's natural and socioeconomic systems to climate change.
- Determine the impacts of CC on the natural and socioeconomic systems of the region.
- Determine a regional response to mitigate those impacts and costs for implementing.
- Implement of mitigative actions (ADAPTATION)
- Build regional capacity to carry out the above actions

The Water Sector is a good example of a priority sector that needs to adapt in the Caribbean and one which is being examined by CARICOM. The principles can be applied across other sectors.

The need to adapt in the Water Sector arises due to (i) increasing variability in the hydrological cycle evident over last 30 years in many parts of world (ii) chances are that this will intensify with global warming (iii) extreme weather events becoming more common and severe and bring mounting human suffering and escalating economic losses.

The problem is that water resources managers previously utilised past records of rainfall and river flows (allowing for evaporation and other losses) to design water management systems. A predictable hydrological cycle meant that reservoir storage volumes and operating rules could be used to balance effect of wet and dry season. However it is no longer feasible to follow this methodology due to fluctuations caused by climate change signals. A strategy that reviews existing water management operations in the light of today's hydrological circumstances – will be part of moving towards coping with future climate change.

Adaptation will involve:

Policy Instruments

- Mainstreaming climate issues into national water management policy.
- Updated assessments of meteorological and hydrological data need to be integral part of water resources management.
- New ways of planning that cut across individual sectors and areas of responsibility .
- Change traditional land use planning practices to give greater weight to new factors such as flood risk, maintaining water supply/demand balance, security of supply, demand side management – pricing policies to encourage, incentives for investments in technological options.
- Integrated Water Resources Management (IWRM)

Technical Measures

- To increase supply e.g. reservoir volumes, water transfers, desalinization.
- Increase efficiency of water use – leakage reduction, use of grey water, more efficient irrigation
- Landscape planning to improve water balance- change land use, reforestation.

Technological and Structural measures

- Access to and use of forecasting and early warning systems based on short- to medium-term weather forecasts
- Increased storage (cope with rainfall and runoff) - Reservoirs – design & capacity; Ground water storage (less evaporation) from storm water runoff, irrigative return flows, reused waste water; rainwater harvesting; water-saving domestic devices- domestic, tourism.

Capacity

- For vulnerability assessments, hazard mapping, risk management approach to factoring climate risks in water resources planning

Public Education and Outreach

Participation

- Of civil society in the articulation of and implementation of policies related to the prudent and sustainable management of water resources

Other adaptive activities for other sectors could include

Risk-sharing and spreading

- New insurance products – crop insurance and micro-insurance mechanisms. Private sector – self-insurance schemes.
- The use of risk-management approach in planning adaptation options for sector.
- Micro-finance schemes for rebuilding.
- The use of alternative methods e.g. crops and planting schedules to spread risks

Change of use, activity or location

- Resettlement
- Prescriptive spatial and land use planning
- Prohibit development in flood plain without necessary safeguards
- Mariculture in inundated low coastal agricultural lands

Some climate science needs in the region that if addressed could enhance the efforts at adaptation:

- Data - restoring and extending hydrological data base; resource inventories; long-term climate data;
- Downscaled climate models – the resolution scale of global models too small and timescale too long to encompass local climate variability.
- Coupling of climate &hydrological models.
- Capacity to forecast climate at basin, regional or national level over seasons or years – short-term forecasting.

Unit 5.4 Mitigation

Key Ideas:

- **Mitigation is a strategy to reduce greenhouse gas emissions.**
- **The region should pursue mitigation, perhaps primarily through renewable energy technologies.**

Key Points:

Mitigation is a **human intervention to reduce the sources or enhance the sinks of greenhouse gases**.

The region is not a large emitter of greenhouse gases (see Figure 22 below). Nonetheless mitigation should be pursued given that the region is the most vulnerable to its impacts.

About Mitigation

- Premised on the "precautionary principle".
- Preventative (proactive) or reactionary strategies to more dangerous anthropogenic interference of the climate systems.
- May have defined timelines.
- Developing, developed and industrial nations will have the greater influence on climate systems. They will need to implement elevated mitigation efforts.
- Targets **the stabilization of greenhouse gas emissions** but does not reduce the amount of greenhouse gases in the atmosphere nor reverse existing effects of climate warming.

Stabilizing CO_2 emissions at their present level would not stabilize its concentration in the atmosphere. Stabilizing the atmospheric concentration of CO_2 at a constant level would require emissions to be effectively eliminated

Cost/benefit decisions should be a major consideration when examining mitigation. "Biggest bang for the buck" principle should apply i.e. – identify greatest impacts when defining the scope of the mitigation efforts.

Carbon trading is a financial incentive driven mechanism to facilitate mitigation locally, bilaterally, regionally. Under the scheme there is a defined market mechanism and agreed price for carbon credits (commodity) or greenhouse gas project development. The mitigation initiative must be measured against a baseline, reported and verified.

Some **mitigation strategies** the Caribbean region must consider:

- Reducing demand for greenhouse gas emission intensive goods and services.

- Increased (energy) efficiency.
- Development and increased use of low-Carbon technologies.
- Reduced fossil fuel emissions (efficiency, reduction or sinks).
- Policy and legislation (national, regional and international).

Some **mitigation technologies** that must be pursued in the region are:

- Energy efficiency and conservation.
- Solar – Thermal, photovoltaic and lighting.
- Wind.
- Hydropower.
- Geothermal.
- Biomass (forestation, fuelwood, fuel cane, cellulosic).
- Biofuels –Ethanol and Biodiesel (3rd and 4th generation –micro algae, synthetic genomics).
- Waste to Energy.
- Blue/Ocean Energy (wave, tidal, current, wind).
- Ocean Thermal Energy Conversion (OTEC).
- Nuclear power.

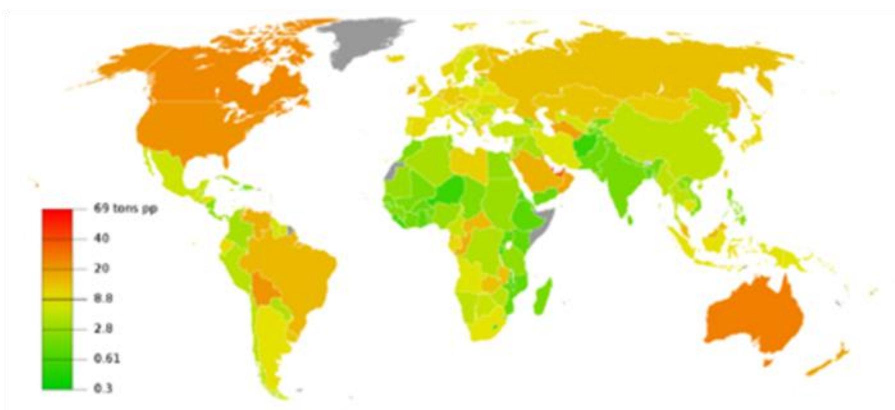


Figure 22 Per capita GHG emissions in 2005, including land-use change. Source: Wikipedia.

Appendices

Appendix A – Sample Schedule

Below is a sample course schedule for offering the course. It is based on an actual offering of the workshop held in Jamaica over 8 days in August 2009. It is meant solely as a guide. Additional optional courses which were done using locally available expertise are shaded in blue. In general lectures were held in the mornings and interactive learning sessions were held after lunch in the afternoons.

Day 1 - Climate Change Basics

- The Earth as an Integrated System
- All you need to know about Greenhouse Gases
- Learning Exercise and Discussion: Emissions Targets
- Interactive Exercise: Global Warming and Global Environmental Change
- Interactive Exercise: Global Warming and Regional Environmental Change

Day 2 - Modelling and Projections I

- Workshop Exercise: Climate Change in My Country
- Deducing the Future: Scenarios and RCPs
- Deducing the Future: GCMs and RCMs
- Learning Exercise and Discussion: Which Scenario?
- Interactive Exercise: Create a Scenario (GCM)

Day 3 - Modelling and Projections I + Modelling and Projections II

- Interactive Exercise: Create a Scenario (RCM)
- Deducing the future from models: Other model variables
- Projections for the Caribbean Region
- Model Limitations and Uncertainties
- Variablity and Seasonal Predictions
- Interactive Exercise: Climate Alphabet Soup

Day 4 – Climate Change Issues

- The Caribbean Modelling Initiative
- The Cost of Climate Change
- The Institutions of Climate Change
- Sectoral Models: Introduction to Impact Modelling

Day 5 - Climate Change Issues

- Communicating Climate Change- The Caribbean Experience
- Field Trip- Glengoffe, St. Catherine

Day 6 – Optional Topics: Vulnerability

- Vulnerability: Methods of Assessment and Linkages to Adaptive Capacity
- Integrated Assessments
- Risk and Vulnerability Assessment Methodology Development Project (RiVAMP)
- Learning Exercise: The Use of Geographic Information Systems in Risk Assessment- With Specific Focus on the RiVAMP Methodology
- Interactive Exercise: Introduction to the Use of GIS in the RiVAMP Methodology
- The Impacts of Climate Change on Coastal Areas
- Interactive Exercise: Hydrological Models

Day 7 – Optional Topics: Adaptation

- Regional Adaptation
- Sectoral Adaptation in the Agricultural Industry
- Adaptation for Coastal Eco-Systems in the Caribbean
- Learning Exercise: A Bottom Up Approach to Building Systemic Resilience to Climate Change
- Interactive Exercise: Community Adaptation Decision Making

Day 8 – Optional Topics: Mitigation

- Introduction to Energy and Climate Change
- Mitigation
- Mitigation Technologies

Appendix B – Workshop Operational Tips

Below are some simple tips that may make for a smooth and engaging workshop.

- Ask participants to bring climate data spanning at least 20 years. If not provide them with a sample time series.
  - If possible get the data beforehand and arrange in a monthly time series in Excel.
  - These data can then be used in ensuing Learning Exercises to create climatologies, seasonalities and indices for individual countries. They would also be sued in the scenario creation exercise.

- Take participants on a field trip
  - This allows them to see firsthand sites that are particularly sensitive to the effects of climate variability as well as adaptation projects that are underway

- Provide opportunities for participants to share information on their countries
  - An informal session during which the attendees present information on not only the climatic context of their countries, but other notable features as well, such as geography, sectoral framework and economically important industries.
  - Use as an ice breaker early in the workshop. Have this session around dinner on the evening of Day 2.

- Choose participants and presenters from a range of areas, countries or regions
  - Attendees have the opportunity to learn about application of climate science in a variety of settings and contexts.

- Administer an easy fun quiz at select points of the proceedings and at the end of the workshop
  - Continuous testing ensures that attendees will review the information they are receiving, and allows them to identify areas in which they may need clarification
  - A quiz at the end tests knowledge gained. Let participants know from Day One about the Quiz. Give them a sample Quiz at the beginning of Day Four so that they can gauge their progress and allay their fears (make it a fair but easy quiz).
  - The quiz at the end can be sued to determine type of certificate awarded.
  - Below is a sample quiz that would be appropriate for such a workshop. It is based on material presented at the Jamaica workshop mentioned previously.

49 Question Quiz

The Earth as an Integrated System

1. The Components of the Earth's System are:
   a. Atmosphere, Ocean & Land
   b. Vegetation, Ice & Living things
   c. Wind and Fire
   d. A & B
   e. All of the Above

2. Evaporation,Transpiration, Condensation and Rain are part of which cycle
   a. Carbon Cycle
   b. Hydrological Cycle
   c. Bi-cycle
   d. None of the above

All you need to Know about Greenhouse Gases,

3. Which of the following are important processes of the Earth's energy budget
   a. Carbon Cycle
   b. Run-off
   c. Reflection of solar radiation
   d. Absorption of solar radiation
   e. C & D

4. Which of the following are greenhouse gases

   a. Nitrogen
   b. Oxygen
   c. Water Vapour
   d. Methane
   e. A,C & D

5. Anthropogenic climate change is due to

   a. greenhouse effect
   b. tectonic activity
   c. An increase in greenhouse gas emissions due to human activity
   d. increase in aerosols concentration

Global warming and Global Environmental Change – Regional Environmental Change

6. What is the most abundant greenhouse gas
   a. Carbon Dioxide
   b. Methane
   c. Water Vapour
   d. Nitrous Oxide

7. The global concentration of CO_2 in our atmosphere today is approximately
   a. 490 ppm
   b. 1260 ppm
   c. 280 ppm
   d. 380 ppm

8. The term global environmental change refers to
   a. Climate Change
   b. Loss of Biodiversity
   c. Land Use Change
   d. None of a,b & c
   e. All of a, b & c.

9. Without a natural greenhouse effect, the mean temperature of the earth would be
   a. About the same as today
   b. About 2 degrees hotter than today
   c. Much, much hotter than today
   d. Actually, much colder than today, about -18 °C
   e. Actually much hotter. About 14°C

10. Sea level rise due to global warming is largely due to:

    a. Melting of the polar ice caps
    b. Expansion of water as it warms
    c. Melting of Greenland Ice Sheets
    d. All of the above

Deducing the Future: Scenarios and RCP's

11. Models + ____________ = Future.

a. High Fashion
b. GCMs
c. Sea Level Rise
d. Scenarios

12. Which of the following is not a scenario grouping developed by the Inter-

Governmental Panel on Climate Change (IPCC)

a. IS92
b. SRES
c. RCPs
d. ISNO

13. Someone told you that the A2 SRES scenario represents futures:

(i) Driven by an economic concern
(ii) Incorporating climate policies to reduce greenhouse gas emissions
(iii) Characterized by high concentrations of GHG's

Which is true?

a. i & iii
b. i & ii
c. ii & iii
d. i, ii & iii

Deducing the Future: GCM's and RCM's

14. Which of the following statements is true?

a. The output of an atmospheric GCM depends only on initial conditions in the atmosphere, independently of the characteristics of the surface.
b. The output of an atmospheric GCM depends on boundary conditions
c. The output of an atmospheric GCM depends on the initial conditions and the prescribed sea surface temperatures
d. The output of an atmospheric GCM depends only of the correct integration of its equations

15. A high resolution RCM, nested in an AOGCM can be a good instrument to:
a. Produce accurate *one month* weather forecasts
b. Produce an accurate high resolution *24 h* prediction of the distribution of ocean currents at a regional level
c. Produce high resolution *global* climate projections for the end of the century using different scenarios
d. Produce high resolution *local* climate projections for the end of the century using different scenarios for the RCM domain.

Deducing the future from Models: Other Model Variables

16. Which one of these variables from a Regional Climate Model (RCM) has a direct link with the tourism sector
a. Cloudiness
b. UV radiation
c. Temperature
d. all of the above

17. A numerical model is
a. A special dish from Jamaican cuisine
b. a mathematical representation of reality
c. a nice body in a swimsuit
d. a new kind of personal computer

18. RCMs give better representation of a GCM in
a. extreme rainfall events and local weather patterns
b. global circulation
c. volcanic eruptions
d. none of the above

Sectoral Models: Introduction to Impact Modelling

19. What Balance equation is considered important to crop models?
a. The energy balance equation
b. The radiation balance equation
c. The water balance equation
d. The biomass balance equation

20. What crop process would you consider more dependent on solar radiation values
a. Photosynthesis
b. Respiration
c. Partitioning of assimilates
d. Phenological development

21. Would an increase in temperature increase the respiration rate of crops
a. No, it will remain unchanged

b. Well, that depends on crop type
c. Yes definitely
d. None of the above

Hydrological Models

22. What are the main causes of flooding in Jamaica?
a. rainfall
b. Lithology i.e. the kind of rocks we have and their structure
c. urbanisation
d. all of the above

23. What are the essential features of the HEC HMS model?
a. Compute runoff from rainfall data alone
b. Compute runoff from rainfall using soil, land use, area of the catchments data
c. Compute runoff and time of runoff using data on soil, land use, rainfall

Model Limitations and Uncertainties

24. Uncertainties in IPCC scenarios are related to**:**
a. Imperfect knowledge of Earth' s radiation balance
b. Climate variability
c. Changes in societal / technological development

25. The purpose of climate change prediction is to**:**
a. Produce a single and precise picture of future climate
b. Build probabilities of possible climates, reflecting different sources of uncertainties
c. Give scientists something to do with their time.

26. Some model's limitations are due to:
a. Insufficient resolution
b. Lack of capacity to explain all physical processes that occur in the atmosphere
c. Communications problems with the authorities.
d. a and b

The Impacts of Climate Change on Coastal Areas

27. Which of the following models is used for Storm surge modelling?
   a. Bruun Rule Model
   b. MIKE 21 Model
   c. Monte Carlo simulation Model
   d. Historical Trend Extrapolation Model

28. How is regional mean sea level best determined?
   a. average of daily readings
   b. average of annual readings
   c. average of decadal readings
   d. through use of satellite altimetry

Communicating Climate Change

29. The **greatest** barrier to communicating climate change is:
   a. lack of media capacity
   b. scientists and their jargon
   c. lack of interest
   d. the complexity of the issue

30. Using music to communicate climate change is effective because:
   a. Anything one-third sings is great
   b. Music has limited reach
   c. It is a great teaching tool as people readily catch on to beats and easily learn lyrics.

Vulnerability: Methods of Assessment and linkages to Adaptive Capacity

31. Resilience refers to:
   a. The ability to respond quickly to a crisis
   b. The ability to recover quickly from a crisis
   c. The ability to plan appropriately for a crisis
   d. The ability to predict or forecast a crisis

32. Risk is:
   a. Vulnerability x coping capacity
   b. Hazard + adaptability

c. Hazard x vulnerability
d. Hazard + vulnerability

Integrated Assessments

33. Which of the following is **not** an advantage of using Integrated Assessment Modelling in Climate Change?
    a. It allows the setting up of simulations based on scenarios for the future
    b. It incorporates mechanisms governing the complex link between economy & environment
    c. It can deal with uncertainty about the future evolution of economic & environmental parameters
    d. It can provide forecasts of future events
    e. It provides a large amount of information about the path of significant policy variables over time

Sectoral Adaptation in the Agricultural Industry - part 1

34. Which of the following would **not** be good criteria for selecting an Integrated Assessment Model?
    a. It closely addresses the question
    b. It produces results at the spatial scale that is most appropriate for the task
    c. It is most appropriate for addressing the key sectors
    d. It hasn't undergone any peer review process
    e. It is appropriate for the target audience

Risk and Vulnerability Assessment Methodology Development Project

35. Which of the following more accurately represents the stages of the RiVAMP tool?
    a. Field Work → Desk Study → Scoping → Analysis → Output →Evaluation
    b. Desk Study → Field Work →Scoping → Output →Evaluation →Analysis
    c. Scoping → Desk Study → Field Work → Analysis → Output →Evaluation
    d. Analysis → Output →Evaluation→Scoping →Desk Study →Field Work

36. Based on the design and objectives of RiVAMP, which of the following countries would most likely **not**, be targeted under the tool?
    a. Antigua and Barbuda
    b. England
    c. Haiti
    d. Belize

37. Which of the following statements best describes why spatial data is well suited for disaster risk assessments?

i. Spatial data has colour information
ii. Spatial data are 3-dimensional
iii. All risk aspects are spatial i.e. have a spatial location and extent

    a. I only
    b. I and III
    c. II and III
    d. II only

38. Could an Early Warning System for agricultural drought be considered an adaptation option to climate change
    a. Yes of course
    b. Not at all
    c. No because drought is not a problem
    d. No because we are not expecting an increase of droughts with climate change

Sectoral Adaptation in the Agricultural Industry - part 2

39. Hurricanes in the Caribbean cause damage and losses for crops because of their:

a. Names
b. Heavy Rainfall and Winds
c. Winds Only
d. Rainfall only

40. Severe Climate Change challenges to the Agricultural sector are:
    a. Fuel costs
    b. Droughts
    c. Sea level rise
    d. B & C
    e. CO2 Emissions

41. Important adaptation Strategies to deal with climate hazards are:
    a. Alternative energy use
    b. Alternative livelihoods
    c. Drought tolerant animals
    d. Drought tolerant crops
    e. B & D

A Bottom Up Approach to Building Systemic Resilience to Climate Change

42. What does the acronym GEF means
    a. Global Environmental Facility
    b. Global Environment Fund
    c. Global Environment Facility
    d. General Environment Facility

43. What does the acronym VRA means
    a. Vulnerability Risk Assessment
    b. Vulnerability Reduction Assessment
    c. Variability Reduction Assessment
    d. Variability Reduction Alternatives

Mitigation

44. Climate change mitigation can be defined as:
    a. A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
    b. A natural cyclical pattern of adjusting climate system variability.
    c. Anthropogenic strategies to tolerate or reduce the impacts of climate change.
    d. An environmental process for ameliorating the impacts of climate change

45. Which combination represents three (3) climate change mitigation options?
    a. Energy efficiency, wind breaks and reduced carbon intensity.
    b. Renewable energy technologies, biofuel mass transit and carbon sink for industry.
    c. Energy efficiency, renewable energy technologies and drought resistant plants.
    d. Early storm warnings, biofuel production and electric-hydrid transportation.

46. Which of the following is <u>not</u> part of an effective policy intervention for mitigation?
    a. Economic, technical and financial considerations.
    b. Regulatory mechanisms for reducing emissions.
    c. Emergency management plans for severe flooding.
    d. Public education

Economics of Climate Change

47. What is an inherent **WEAKNESS** in using partial equilibrium models to assess climate change impacts in the Caribbean?

a) They are unable to capture system/economy-wide effects
b) They incorporate technological substitution
c) They are usually viewed as top-down models and do not capture views at the grass-roots
d) They are generally more beneficial to the Caribbean situation

48. How does the Caribbean Community Climate Change Centre (CCCCC) carry out its activities with Member Countries of the Caribbean Community (CARICOM)?

a) Through phone calls
b) Through the internet
c) Through the signing of Memoranda of Understanding (MoU)

d) Through establishing contact with the political directorate in the member countries

Field Trip

49. What two hazards is the Glengoffe project adapting to:

a. Heavy Rainfall and Drought
b. Forest Fires and earthquakes
c. Forest Fires and Drought
d. Volcano and Earthquake

Appendix C – Some Useful Links

Caribbean Community Climate Change Centre (5Cs)
http://www.caribbeanclimate.bz/

European Union
http://europa.eu/index_en.htm

Global Climate Change Alliance (GCCA)
http://www.gcca.eu/pages/1_2-Home.html

Climate Studies Group, Mona (CSGM)
http://myspot.mona.uwi.edu/physics/csgm/home

Instituto de Meteorología de la República de Cuba (INSMET)
http://www.insmet.cu/asp/genesis.asp?TB0=PLANTILLAS&TB1=INICIAL

Caribbean Institute for Meteorology and Hydrology (CIMH)
http://www.cimh.edu.bb/?p=home

PRECIS Caribe
http://precis.insmet.cu/eng/Precis-Caribe.htm

Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch/
http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

UN Framework Convention on Climate Change (UNFCCC)
http://unfccc.int/2860.php
http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

UNDP Climate Change Country Profiles
http://country-profiles.geog.ox.ac.uk/

The CARIBSAVE Partnership
http://www.caribsave.org/

The Panos Institutes
http://www.panos.org/

Global Environment Facility Small Grants Programme (GEF SGP)
http://sgp.undp.org/

REFERENCES

Climate Studies Group, Mona (CSGM), 2012: State of the Jamaica Climate: Past and Future. Information for Resilience Building. For Pilot Project for Climate Resilience. GOJ. 180 pp.

Fleming, K., Johnston, P., Zwartz, D., Yokoyama, Y., Lambeck, K., & Chappell, J. (1998). Refining the eustatic sea-level curve since the Last Glacial Maximum using far-and intermediate-field sites. *Earth and Planetary Science Letters*, *163*(1), 327-342.

Goosse H., P.Y. Barriat, W. Lefebvre, M.F. Loutre, and V. Zunz (2010). Introduction to climate dynamics and climate modeling. Online textbook available at http://www.climate.be/textbook.

Houghton, John T., L. G. Meiro Filho, Bruce A. Callander, Neil Harris, Arie Kattenburg, and Kathy Maskell, eds. *Climate change 1995: The science of climate change: contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change*. Vol. 19390. Cambridge University Press, 1996.

Houghton, John Theodore, Y. D. J. G. Ding, David J. Griggs, Maria Noguer, Paul J. van der LINDEN, Xiaosu Dai, Kathy Maskell, and C. A. Johnson. *Climate change 2001: the scientific basis*. Vol. 881. Cambridge: Cambridge University Press, 2001.

Metz, B., Davidson, O., Swart, R., & Pan, J. (Eds.). (2001). *Climate change 2001: mitigation: contribution of Working Group III to the third assessment report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Peterson, Thomas C., et al. 2002: "Recent changes in climate extremes in the Caribbean region." *Journal of Geophysical Research* 107.D21.

Solomon, Susan, Dahe Qin, Martin Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller. "The physical science basis." *Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change* (2007): 235-337.

Taylor, M. A., Centella, A., Charlery, J., Borrajero, I., Bezanilla, A., Campbell, J., Rivero, R., Stephenson, T. S., Whyte, F., Watson, R. (2007). *Glimpses of the Future: A Briefing from the PRECIS Caribbean Climate Change Project,* Caribbean Community Climate Change Centre, Belmopan, Belize. 24 pp.

Watson, Robert T., Marufu C. Zinyowera, and Richard H. Moss, eds. *The regional impacts of climate change: an assessment of vulnerability*. Cambridge University Press, 1997