United Nations
Framework Convention on Climate Change

Fellowship Programme

The Status of Climate Change Data: A Case Study for Trinidad and Tobago

Joanne Chin Sang
Fellow

2 February – 30 June, 2015

Executive Summary

Scientific evidence has been the driving force behind the international action to combat the complex issues of climate change. Such evidence has indicated that the current rate of greenhouse gas emissions into the atmosphere will lead to dangerous anthropogenic interference with the climate system, unless there is intervention. At present, impacts are already being felt. It is now well established that the two modes of action in the efforts to promote a sustainable future is the stabilization of greenhouse gas emissions in the atmosphere by transitioning to a low-carbon economy, with a long term global goal (LTGG) of under 2^{o}C above pre-industrial levels by 2100, and adaptation for the building of climate resilience. While both measures to limits the adverse impact ought to be given equal weight and executed simultaneously, Small Islands Developing States (SIDS) such as the focus of this study, Trinidad and Tobago, are extremely susceptible and adaptation should not be delayed. Climate data plays a critical role in understanding and assessing the situation and informing the way forward.

Recognizing the importance of climate data, articles 4.1(g) and 5 of the United Nations Framework Convention on Climate Change (UNFCCC) mandated Parties to promote and cooperate in systematic observation of the climate system, including through support to existing international programmes and networks. The implementation bodies of such programmes and networks include the Global Climate Observing System (GCOS) and World Meteorological Organization (WMO), among other agencies. In February, 2015, a workshop was hosted by GCOS in collaboration with the Intergovernmental Panel on Climate Change (IPCC) and the UNFCCC, to consider the observational and research needs that could enhance systematic observations and related capacity, especially in developing countries, in order to assess climate change risks and support adaptation planning. One of the recommendations from this workshop was to conduct one or more well described case studies on non-annex I Parties[1] to demonstrate the value of systematic observations/projections to adaptation and gain specific insight on possible gaps.

This study aims to review and determine the status of data used in informing climate change adaptation programmes within Trinidad and Tobago for the purposes of identifying gaps and making recommendations for greater efficiency, including adherence to guidelines and standards by the UNFCCC and their collaborating systematic observation bodies and considerations for regional downscaling of international data models, such as from the IPCC. The approach involved a review of literature and liaisons with key persons to provide insight into the present climate data situation for Trinidad and Tobago, as well as the Caribbean region, with reference to a specific on-going climate change adaptation project. Systematically observed data was the focus of the review but the study also touched briefly on the data used in a recent socio-economic analysis of climate change adaptation in Trinidad and Tobago.

[1] Available at: < http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php>

The findings revealed that some infrastructure currently exists for climate data. The essential climate variables rainfall, temperature, relative humidity, wind direction and wind speed are collected by nine (9) weather stations, two (2) of which are manned stations and seven (7) of which are automated stations. However, it was determined that only the manned weather stations are considered reliable and are used to supply regional and international databases. This was viewed as one of the main data challenges and results from lack of capacity and resources to maintain the non-manned stations. Various states agencies were found to produce geospatial data and a major project is currently underway for the development of a National Spatial Data Infrastructure (NSDI). A Council was established in November, 2014 for the NSDI and their mandates are a good example of elements that should be considered in devising a climate data strategy. The local sea level rise monitoring instruments are out-of-date and considered unreliable and there is now consideration for the use of a high-tech monitor installed by the National Oceanic and Atmospheric Administration (NOAA), off the coast of Puerto Rico, to determine values for Trinidad and Tobago.

Regarding information portals and scenario data, sources of data could be found through both regional and international channels. A number of global portals exist, which contain a wealth of climate data, including scenarios, for various regions of the world. However, while data could be found for Trinidad and Tobago at these portals, the standard resolution size is approximately 300 km^2, which is too low for any real detail to be obtained. This resolution size is equivalent to the entire size of the island of Tobago and many other islands in the Caribbean, thereby posing a major limitation in the use of global databases.

The Caribbean Community Climate Change Centre (CCCCC), which is the coordinating centre for the region's climate change response, is well equipped with a data portal containing a wide range of climate data and model scenarios specific to the Caribbean. The centre collaborates with a number of international organizations and is involved in a number of programmes that promotes efficient data collection, creation, storage and management for the region, such as the Coordinated Regional Climate Downscaling Experiment (CORDEX). They are also involved in regional downscaling of data, which is supplied through their information portal known as the Clearinghouse[2], at a resolution of 50 km^2. The centre recently launched a Caribbean Weather Impacts Group (CARIWIG) project that increases the resolution of regional data to 25 km^2 and is continuing partnerships to pursue downscaling to an even higher resolution that would allow for impacts to be taken into consideration. At recent events held by the UNFCCC, namely the 2015 National Adaptation Plans (NAP) Expo and the 2015 Bonn Climate Change Conference, the CCCCC was praised by Parties for being a model to guide other similar regions, such as the Indian and Pacific Ocean islands. However, challenges were still noted by the centre, which includes the funding, management, preservation and dissemination of data collection through the state.

The on-going local climate adaptation project referenced in this study, the Global to Local Climate Change Adaptation and Mitigation Scenarios (GoLo CarSce), highlighted

[2] Available at: <http://clearinghouse.caribbeanclimate.bz/?db_type=Climate Model:>

the usefulness of data in informing adaptation strategies. It involves the use of downscaled climate data through various sources for the development of future scenarios of the most vulnerable sectors to climate change. In Trinidad and Tobago, the most vulnerable sectors were found to be agriculture, human health, human settlements, coastal zones, water resources and the energy sector.

Owing to the various gaps noted in the climate data review for Trinidad and Tobago, a number of recommendations were given to specifically target the issues unique to the country, with the view of promoting a more integrated approach to climate data management. It should also be noted that many of the specific challenges being faced in Trinidad and Tobago are also being experienced by many other developing countries. There is a need for improved data coverage via the capacity and resources to maintain or implement more weather stations. Data rescue of the historical or incomplete data should also be considered due to the quantity of data that still remains incompatible with present data systems. In light of conflicts with the cost and resources involved in data creation and lack of willingness to share, considerations should be made towards the development, maintenance and support of data protection and data sharing polices.

Collaborative mechanisms and coordination among different agencies on a national, regional and international scale are paramount in ensuring that the most relevant information and guidelines are shared by the international regulatory and research bodies, while they receive localized data to conduct their assessments and develop further guidelines as required by the constantly changing pace of technology. Local sectoral collaboration also prevents duplication of efforts and wastage of resources. Also, in line with adapting to changing technology, there should be enhancement and better overall coordination of capacity building for data climate specialists. In additional to accommodating for new and emerging fields, the updating and enhancing of skills in the current fields are also lacking.

In keeping with the guidelines for the NAP, it is recommended that climate studies are guided by the best available science, including considerations for traditional and indigenous knowledge in contributing to data needs. The concept of ‘ground truthing’ plays a vital role in ensuring accuracy of data or filling of data gaps in areas, in a way that could not be determined otherwise through systematic observations. As detailed in the CCCCC’s regional downscaling effort, there is also a need to improve regional downscaling of global data models. And lastly, the recommendation for an integrated national approach to climate data management is reiterated. A balanced and effective climate data management system would require that all factors be taken into consideration – systematic observations, socio-economic data and the needs of the various sectors in informing climate change actions and building climate resilience.

Acknowledgements

I wish to express my deep gratitude to a number of persons who contributed to a rewarding fellowship experience and made this case study possible. Firstly, I would like to thank the UNFCCC Secretariat and the Government of Norway for providing this fellowship programme opportunity. It has undoubtedly been a uniquely enriching experience that has provided invaluable exposure to the world's largest climate change undertaking.

In particular, I would like to thank my supervisor of the past five months, Florin Vladu, Manager of the Science and Review sub-programme under the Adaptation programme, and his team. His guidance has been inspiring and strategic in providing a holistic insight into the work of not only the sub-programme, but also the grander UNFCCC agenda. Also, his assignment of this case study has strategically facilitated my understanding of each component of the sub-programme's work and fits the purpose of the fellowship in enabling my contribution to the research and systematic observation agenda, while also promoting further work on this subject matter to be explored upon my return to Trinidad and Tobago. I also wish to thank Paul Desanker, Manager of the National Adaptation Plans sub-programme and his team, for guidance and information on the NAP as they related to this study. I am thankful also to the Finance, Technology and Capacity-Building (FTC) programme for facilitating this fellowship, along with the Adaptation programme.

I extend sincere gratitude to John Agard, Head of the Department of Life Sciences, Faculty of Science and Technology, the University of the West Indies (UWI); member of the IPCC and Team Leader of the GoLo CarSce Project, for his guidance from the inception of my work on this case study. I am also very grateful for the input provided by the CCCCC, through Timo Baur Clearinghouse Manager/ Information Systems Advisor, for his extremely thorough addressing of my questions, as well as Carlos Fuller, International and Regional Liaison for his very helpful presentations made at two events that I attended while in Bonn.

I would also like to thank Bheshem Ramlal, Head of the Department of Geomatics Engineering and Land Management, UWI and Chairman of the NSDI Council, as well as Arlene Aaron-Morrison, Climatologist at the Trinidad and Tobago Meteorological Service (TTMS) for the very detailed information they provided on geospatial data and weather and climate data respectively. And I am also extremely grateful to the National Institute of Higher Education, Research, Science and Technology (NIHERST) in Trinidad and Tobago for their endorsement, encouragement and facilitation in entering this fellowship programme.

And lastly, I wish to acknowledge my UNFCCC colleagues who contributed to an amazing experience, as well as my family and friends, in particular Kurt Leong Poi, who provided unlimited support throughout this journey.

Table of Contents

Abbreviations

ACP - African, Caribbean and Pacific Group of States
AOSIS – Alliance of Small Island Developing States
AR5 - Fifth Assessment Report
CARDI - Caribbean Agricultural Research and Development Institute
CARICOM - Caribbean Community and Common Market
CARIWIG - Caribbean Weather Impacts Group
CCAFS - Climate Change, Agriculture and Food Security
CCCCC - Caribbean Community Climate Change Centre
CCKP - Climate Change Knowledge Portal
CEOS - Committee on Earth Observation Satellites
CGIAR - Consultative Group for International Agricultural Research
CIAT - International Centre for Tropical Agriculture
CMIP - Coupled Model Intercomparison Project
CORDEX - Coordinated Regional Climate Downscaling Experiment
CRU - Climate Research Unit
DDC - Data Distribution Centre
ECA&D - European Climate Assessment & Dataset
FAO - Food and Agriculture Organization of the United Nations
GCM - Global Climate Model
GCOS - Global Climate Observing System
GDP - Gross Domestic Product
GFCS - Global Framework for Climate Services
GHCN - Global Historical Climatology Network
GHG - Greenhouse Gas
GIS - Geographic Information Systems

GoLo CarSce - Global-Local Caribbean Climate Change Adaptation and Mitigation Scenarios
GORTT - Government of the Republic of Trinidad and Tobago
GOSIC - Global Observing Systems Information Center
HCV - High Conservation Value
HDI - Human Development Index
IDB - Inter-American Development Bank
IIASA - International Institute for Applied Systems Analysis
IMAGE - Integrated Model to Assess the Globe Environment
IOC-UNESCO - Intergovernmental Oceanographic Commission of UNESCO
IPCC - Intergovernmental Panel on Climate Change
KNMI - Kononklijk Netherlands Meteorological Institute
LTGG - Long-term Global Goal
NAP - National Adaptation Plans
NCOF - National Climate Outlook Forum
NIHERST - National Institute of Higher Education, Research, Science and Technology
NOAA - National Oceanic and Atmospheric Administration
NSC - National Stakeholder Consultation on Climate Services
NSDI - National Spatial Database Infrastructure
PAN - Protected Area Networks
PRECIS - Providing REgional Climates for Impacts Studies
PROVIA - Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptation
RCP - Representative Concentration Pathway
RSO - Research and Systematic Observation
SBI - Subsidiary Body for Implementation
SBSTA - Subsidiary Body for Scientific and Technological Advice
SIDS - Small Island Developing States
SLR - Sea Level Rise
SO - Systematic Observation
SSPs - Socio-Economic Pathways
TGCIA - Task Group on Data and Scenario Support for Impact and Climate Analysis
TTMS - Trinidad and Tobago Meteorological Services
UNDP - United Nations Development Programme
UNEP - United Nations Environment Programme
UNESCO - United Nations Educational, Scientific and Cultural Organization
UNFCCC - United Nations Framework Convention on Climate Change
UN-SPIDER - United Nations Platform for Space-based Information for Disaster Management and Emergency Response
UWI - University of the West Indies
WASA - Water and Sewerage Authority of Trinidad and Tobago
WCRP - World Climate Research Programme
WMO - World Meteorological Organization
WRA - Water Resources Agency
WRF - Weather Research and Forecasting

List of Figures

List of Table

Chapter 1: Project Introduction

1.1 Overview Structure of Fellowship

The ultimate aim of the United Nations Framework Convention on Climate Change (UNFCCC) is to prevent dangerous anthropogenic interference with the climate system by stabilization of greenhouse gas concentrations in the atmosphere. The UNFCCC secretariat supports 195 Parties to the Convention and 192 Parties to the Kyoto Protocol[3] in international climate change negotiations, through various programmes, which are aligned to their long term global goal (LTGG) of reducing emissions so that global temperature increases are limited to below 2^{o}C above pre-industrial levels.

In celebration of the International Year of Small Island Developing States (SIDS) in 2014, the UNFCCC secretariat offered two five-month fellowships to young professionals from the region, interested in contributing to the work on climate change adaptation or on gender and youth related dimensions of climate action. The programme aims to link the work of the Convention to the national climate change agenda of each fellow's home country with a view for continuity of the work upon his/her return. Being one of the recipients of this prestigious award, I was placed in the Adaptation programme under the Science and Review (S&R) sub-programme.

The UNFCCC refers to adaptation as adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. The science and review aspect of the Adaptation programme focuses on the foundational climate science that guides appropriate decisions and actions. The S&R sub-programme is comprised of two main work streams – Research and Systematic Observation (RSO) and the 2013-2015 Review, and is also the main liaison with the Intergovernmental Panel on Climate Change (IPCC)[4].

Figure 1 shows the work plan of the S&R sub-programme during the term of fellowship, 1 February – 30 June, 2015. The RSO agenda is broken down into systematic observation (SO) and research. During 10 - 12 February, 2015 a workshop entitled "Enhancing observations to support preparedness and adaptation in a changing climate - Learning from the IPCC Fifth Assessment Report" was hosted by the Global Climate Observing System (GCOS) in collaboration with IPCC and UNFCCC. This case study is a product of a recommendation made during this workshop to undertake one or more well-described case studies on non-annex I Parties to demonstrate the value of systematic observations/projections to adaptation and gain specific insight on possible gaps. The case study approach is outlined in chapter 2 of this report.

[3] An international agreement linked to the UNFCCC, which commits its Parties by setting internationally binding emission reduction targets.
[4] The IPCC is an independent body founded under the auspices of WMO and UNEP. It assesses the scientific literature and provides vital scientific information to the climate change process, with inputs from hundreds of scientists.

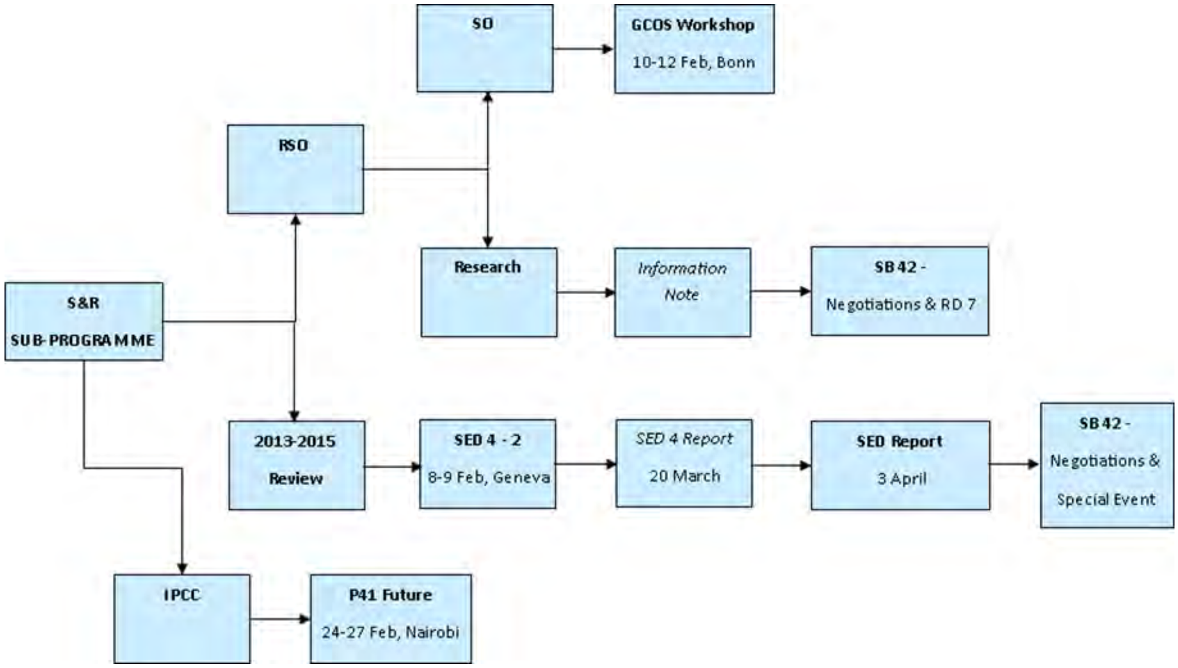


Figure 1.1: S&R sub-programme work plan during fellowship period

The research part of the agenda focused on the seventh meeting of the research dialogue (RD7) and the negotiations which were held during the forty-second session of the Subsidiary Body for Scientific and Technological Advice (SBSTA 42) at the Bonn Climate Change Conference in June, 2015. An information note to prepare Parties for the session was produced prior to the SBSTA 42[5]. The two themes of RD7 were addressing data and information gaps, including from the IPCC and lessons learned and good practices for knowledge and research capacity building, in particular in developing countries. During the negotiations, Parties agreed that and the SBSTA encouraged the scientific community to address information and research gaps identified during the research dialogue, including scenarios that limit warming in 2100 to below 1.5°C relative to pre-industrial levels, and the range of impacts at the regional and local levels associated with these scenarios[6]. The SBSTA also thanked the secretariat for the summary report[7], requested at SBSTA 40, on the progress made in further enhancing the availability and visibility of scientific information relevant to the Convention on the UNFCCC website and encouraged continued efforts[8].

During the fellowship, I was able to contribute to some of the activities covered in the summary report, under both RSO and 2013-2015 Review. RSO items included input to the knowledge resources via the science calendar update for 2015 and 2016 and compiling of links to events of partner organizations. I also provided recommendations for topical scientific articles of partner organizations for posting onto the social media pages, provided an information update on the S&R sub-programme for the UNFCCC E-

[5] Available at: < http://unfccc.int/files/science/workstreams/research/application/pdf/rd7_infnote.pdf>
[6] FCCC/SBSTA/2015/L.4, paragraph 5.
[7] Available at: < http://unfccc.int/resource/docs/2015/sbsta/eng/inf01.pdf>
[8] FCCC/SBSTA/2015/L.4, paragraph 4.

Newsletter and provided input into the science essential background of the UNFCCC webpage, including simplification of slide animations from the IPCC on climate change reasons for concern and the relationship between risks from climate change, temperature change, cumulative CO_2 emissions and changes in annual GHG emissions by 2050. Figure 2 shows the current and projected scenarios for the relationship above. This diagram shows that even at present day, impacts are being observed and are expected to worsen with increasing CO_2 emissions and the subsequent rise in temperatures.

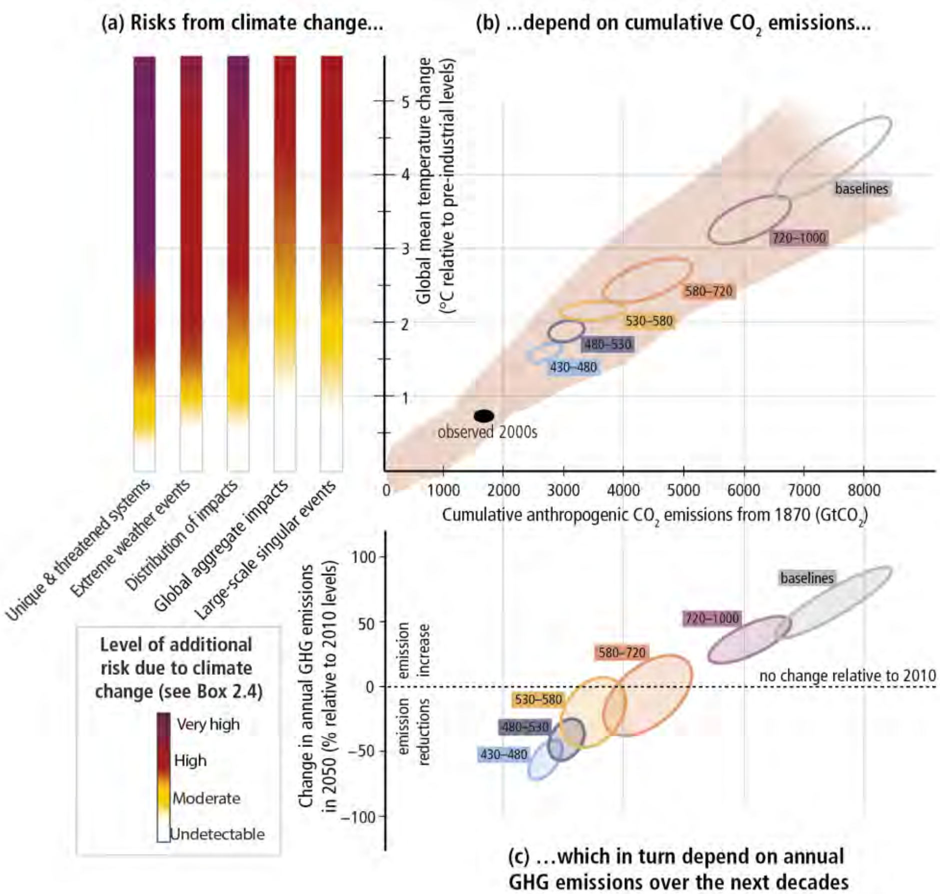


Figure 1.2: Relationship between increase in risk (a) due to increase in temperature resulting from CO_2 emissions (b) and changes in annual GHG emissions by 2050 (c)
(*Source: IPCC AR5 – Synthesis Report, SPM*)

The Structured Expert Dialogue (SED) on the 2013-2015 review was established to consider these and other scientific findings on the adequacy and overall progress made towards the long-term global goal as well as the strengthening of the goal. It involved face-to-face dialogues with over 70 experts, which took place during five meetings from June 2013 to February 2015, as mandated in 2/CP.17, paragraph 158 of the Convention. The goal of the SED was to bridge the gap between science and policy, to ensure the scientific integrity of the 2013–2015 review and to produce a final report[9] for consideration during the SBSTA 42 and Subsidiary Body for Implementation (SBI) 42, collectively known as SB 42. The report yielded ten (10) messages as outline in Annex I.

[9] Available at: < http://unfccc.int/resource/docs/2015/sb/eng/inf01.pdf>

The overall findings of the report indicated that we are not on track in meeting the LTGG and emission rates are continually accelerating. As climate related impacts are already being felt at present, the LTGG should be viewed as a 'defence line' or 'buffer zone', instead of a 'guardrail' up to which all would be safe. Although the science is less robust for the 1.5^{o}C scenario, some regions would be better safe guarded if the defence line is pushed as low as possible. Mitigation, adaptation, finance, technology and capacity-building efforts would therefore need to be significant and immediate, in particular to minimize effort and remain cost-effective. Additionally, carbon neutrality should be achieved in the second half of this century in order to achieve the LTGG. For the 1.5^{o}C scenario, this would mean scaling up efforts even further, which may have greater implications for costs and development for these vulnerable regions. Also, the 1.5^{o}C would not be possible by the end of the century as a result of the lag in the concentration of current emissions in the atmosphere, even if new emissions were to cease entirely.

My involvement in the 2013-2015 review included identifying audio files and webcasts that complemented the website text on the SED. I was also involved in the analysis of the procedural elements of the SED, which contributed to the technical summary of the report. However my greatest involvement and learning experience from the process was my support role to my supervisor, Florin Vladu, for the 2013-2015 review agenda item during the SBSTA/SBI 42. For this event, I was responsible for preparing speaking notes for the opening plenary, the SED special event and the joint contact groups and informal consultations. Additionally, I was involved in planning meetings, assistance in drafting text on-screen during sessions, note-taking, updating of the agenda item on the UNFCCC Session 2015 portal and advertising the SED special event on the main web page.

During the fellowship, I attended the National Adaptation Plans (NAP) Expo and the Adaptation Committee (AC)/ Least Developed Countries Expert Group (LEG) Workshop in April, 2015, where I gained further insight into guidelines of data in adaptation planning through expert presentations and discussion among Parties. My areas of focus were science and knowledge and best practices to implement the NAP with considerations for data. The event also allowed for networking and identification of a presenter to speak on the topic of regional downscaling for the Caribbean region at the RD7. Further details on the relevance of the NAP to this study can be found in section 1.7 of this report.

The overall structure of the fellowship programme provided a level of immersion in each component of the sub-programme to which I was assigned, all of which are reflected within this case study report, with an additional holistic view of the Convention's work at an international level to its translation to regional and national levels.

1.2 Aim

The aim of this case study is to determine the status of data used in informing climate change adaptation programmes within Trinidad and Tobago for the purposes of identifying gaps and making recommendations for greater efficiency based on guidelines and standards by the UNFCCC and their collaborating systematic observation bodies.

1.3 Objectives

The objectives of this study are:

- To investigate the current status and developmental direction of the climate data infrastructure and identify existing gaps and/or challenges.
- To determine the various sources of data that may be used to inform climate change programmes within Trinidad and Tobago, using an example of an on-going climate change adaptation programme.
- To provide recommendations on the way forward based on internationally established guidelines.
- To inform the UNFCCC and their relevant collaborating bodies on the data situation from a regional perspective, using this case study as a starting point.

1.4 Key Questions

- How are systematic observations/projections and other data being used to inform climate change decision-making?
- Are the climate data needs of Trinidad and Tobago being sufficiently met?
- How best can gaps in climate data be addressed for Trinidad and Tobago?

1.5 Key Challenge

The key challenge being faced is developing efficient integrated observation and modelling systems, as well as socioeconomic systems that effectively address the needs of vulnerable sectors, resources, and investment strategies, in the context of achieving the LTGG of 2^{o}C or even 1.5^{o}C.

1.6 Background

1.6.1 Overview of Climate Change Data

Climate information and prediction enables better management of the risks associated with climate variability and adaptation. High quality systematic observations of the Earth's climate and other variables are the foundation for informing solid decision-making on future action on climate change and are instrumental in informing planning, policy and practice.

According to articles 4.1(g) and 5 of the United Nations Framework Convention on Climate Change (UNFCCC), Parties are required to promote and cooperate in systematic observation of the climate system, including through support to existing international programmes and networks. The process of climate observation taking into consideration inputs, implementation, outputs and decisions is outlined in figure 1.3[10]. One of the main implementation bodies, GCOS, has identified a set of 50 Essential Climate Variables[11] (ECVs), which are feasible for global implementation and are needed to understand, predict and manage countries' responses to climate change.

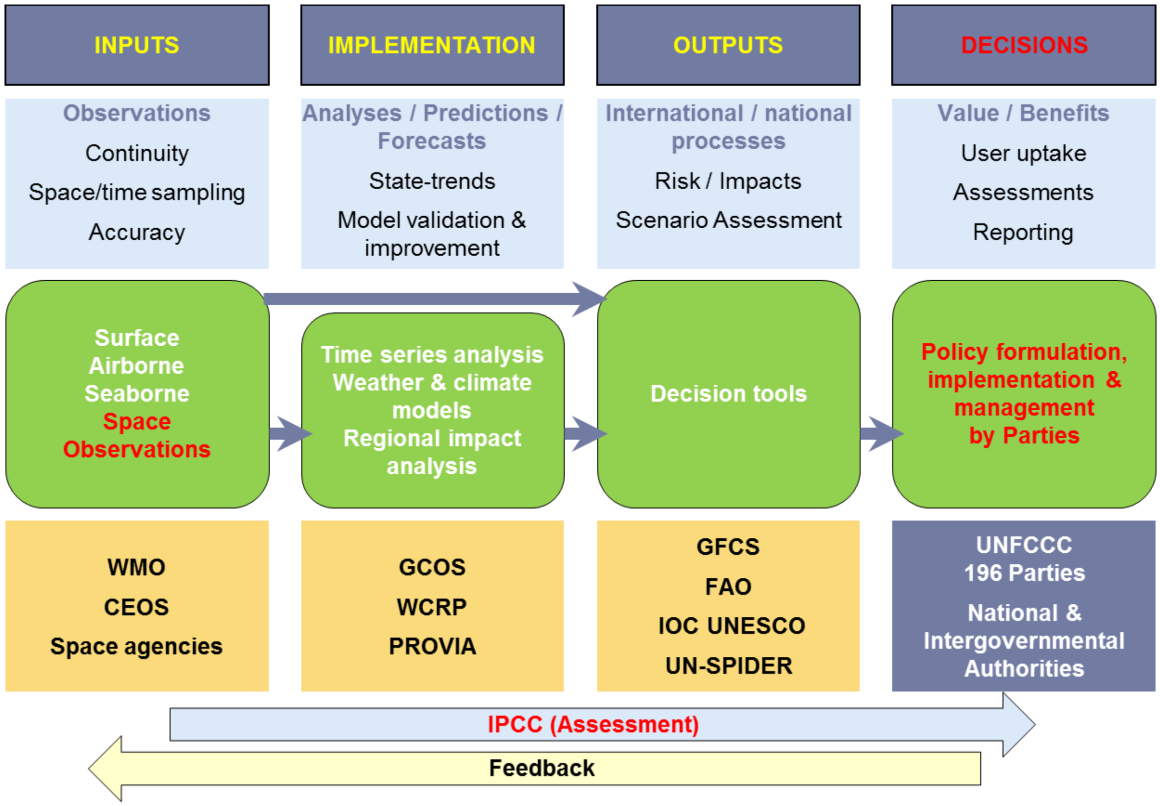


Figure 1.3: The process of climate observation – from inputs to decisions
(Source: Vladu, 2015)

At the forty-first meeting of the Subsidiary Body for Scientific and Technological Advice (SBSTA 41) in Lima, Peru in 2014, the SBSTA re-emphasized the importance of systematic observation for the UNFCCC process at large and the continued need to secure funding to meet the essential needs for national, regional and global climate observations under the Convention on a long term basis[12].

According to Pulwarty (2015), the current availability and quality of climate observations and impacts data to support adaptation appear to be inadequate for large parts of the globe. A comprehensive climate observing system capable of testing climate predictions with sufficient accuracy or completeness is lacking. According to Wielicki et al (2013) (as cited in Pulwarty, 2015), the economic value of advanced climate observing systems is dramatically larger than their cost.

[10] Refer to pages (vi and vii) for elaboration of abbreviations.
[11] Available at: < http://www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables>
[12] FCCC/SBSTA/2014/L.19

The workshop held in February, 2015 by GCOS in collaboration with IPCC and UNFCCC, aimed to assess the IPCC's findings in the context of data availability, defining data guidelines, characterizing national and regional data needs for relevant sectors and identifying paths for addressing institutional and local capacities for data and networks that relate to climate adaptation programmes. Workshop participants considered the observational and research needs that could enhance systematic observations and related capacity, especially in developing countries, and aid in assessing the risks of climate changing and support adaptation planning (GCOS, 2015) .

According to the workshop report, participants agreed that adaptation planning and assessment requires a combination of baseline climate data and information, coupled with sector-specific and other economic and demographic data at regional, national and local scales. The workshop also yielded outputs of good data quality, standardization and open access being essential and that there be clear descriptions of the complete chain of observations-data-information-adaptation. GCOS and other partner have been tasked with evaluating and delivering the best methods for developing adaptation strategies as well as providing guidance, guidelines, or references to other sources of advice, on data and sources of products, as well as their limitations.

This case study is meant to determine the status of data used in informing climate change adaptation programmes within Trinidad and Tobago, as per recommendation from the workshop to undertake case studies on non-annex I Parties. Such case studies are expected to promote coordination amongst observation systems at different scales from sub-national to global, allowing for adaptation needs to be better informed.

1.6.2 The Climate Change Situation for Trinidad and Tobago

Trinidad and Tobago is a twin-island state in the southern Caribbean, located northeast of Venezuela and south of Grenada. The country occupies an area of 5,128 square kilometres with a population of approximately 1.3 million people. Trinidad is the larger and more populous island, while Tobago is the smaller island and comprises only six per cent of the nation's land area and four per cent of the population. The climate is tropical and is divided into a dry season from January to May and a wet season from June to December.

The country is mostly plains with some hills and low mountains and boasts of a rich biodiversity relative to size. This is mainly attributed to its continental origin, proximity to the Orinoco River, topographical features and microclimate variability. According to the Government of the Republic of Trinidad and Tobago (2010), the main ecosystems are: coastal and marine (coral reefs, mangrove swamps, ocean and seagrass beds); forest; freshwater (rivers and streams); karst; man-made ecosystems (agricultural land, freshwater dams, secondary forest); and savanna. The country's biodiversity play an important role in many of the ecosystem services that support human well-being, directly - through the provision of freshwater, forest products and fisheries and indirectly - through a number of biophysical processes and amenities.

In contrast to many other Caribbean countries, whose economies are tourism based, Trinidad and Tobago's economy is energy based. Oil and gas production contributes to 46 per cent of the nation's Gross Domestic Product (GDP) and although Tobago's economy is more focused on tourism, this only account for around 1 per cent of the nation's combined GDP. USDS (2010) (as cited in Adaptation Learning Mechanism, 2015) indicates that the per capita income of the country is approximately US$18,864 per year and UNDP (2015) cites its Human Development Index (HDI) value for 2013 as 0.766 - which is in the high human development category and positions the country at 64 out of 187 countries and territories.

Trinidad and Tobago are among 51 small island developing states (SIDS) that are especially vulnerable to the effects of climate change as a result of to their developing status, small physical size, low-lying coastal areas, low availability of resources, small but rapidly growing population and increasing pressures on natural resources, remoteness, susceptibility to natural disasters, excessive dependence on international trade and vulnerability to global developments. In addition to these factors, SIDS also possess limited financial, technical and institutional capacity for adaptation thereby enhancing their vulnerability and reducing their resilience to climate variability and change (UNFCCC, 2007). It is very likely that in the 21st century and beyond, sea level change will have a strong regional pattern, with some places experiencing significant deviations of local and regional sea level change from the global mean change (IPCC, 2013). This is especially the case for SIDS, where the sea level rise is expected to be greater, posing a significant concern, as capital cities of SIDS, including Trinidad and Tobago, have historically been established near the coast for ease of import and export activities.

According to Nurse (2015), observed temperature changes in the Caribbean reflect global trends, with more warm days and warm nights as well as fewer cool days and cool nights. A $1^{o}C$ to $4^{o}C$ warming (relative to 1960-1990 mean) is projected by the end of the century (refer to Appendix A – figure 1). The mean annual rainfall over the Caribbean, from 1900-2000, showed a consistent decline by around 0.18 mm yr-1 and a 25-30% decrease in rainfall is projected before the end of century (refer to Appendix A – figure 2). Drying far exceeds natural variability and drier wet seasons are likely (Taylor, 2011) (as cited in Nurse, 2015). However, the number of heavy rainfall events has increased within the last 75 years. It is also predicted that climate change will result in an increased frequency of extreme events such as tropical storms and hurricanes. The observed pattern for sea level rise in SIDS over the 20^{th} century is outlined below and as indicated in the previous paragraph, the rate of rise is expected to be greater than the global average in the 21^{st} century.

- Tropical Western Pacific - rate of rise is almost 4 times the global average
- Indian Ocean - rate of rise as much as twice global average
- Caribbean - rate of rise generally higher than global average, at approximately 1.8mm yr-1
- Guyana - observed mean rate of rise was approximately 2.4 mm yr-1

Many sectors within Trinidad and Tobago and the greater Caribbean have already been experiencing adverse impacts from these effects of climate change, and these are expected to worsen even if the UNFCCC's LTGG of 2^{o}C is achieved. During the 2013-2015 review agenda item at the SBSTA 42 and the SBI 42, Parties belonging to the Alliance of Small Islands States (AOSIS) advocated for a defence line of 1.5^{o}C instead of 2^{o}C. Figure 1.4 shows the climate change risks for SIDS and the ocean in the short, medium and long term, taking into account the LTGG and business as usual scenarios, as well as adaptation potential.

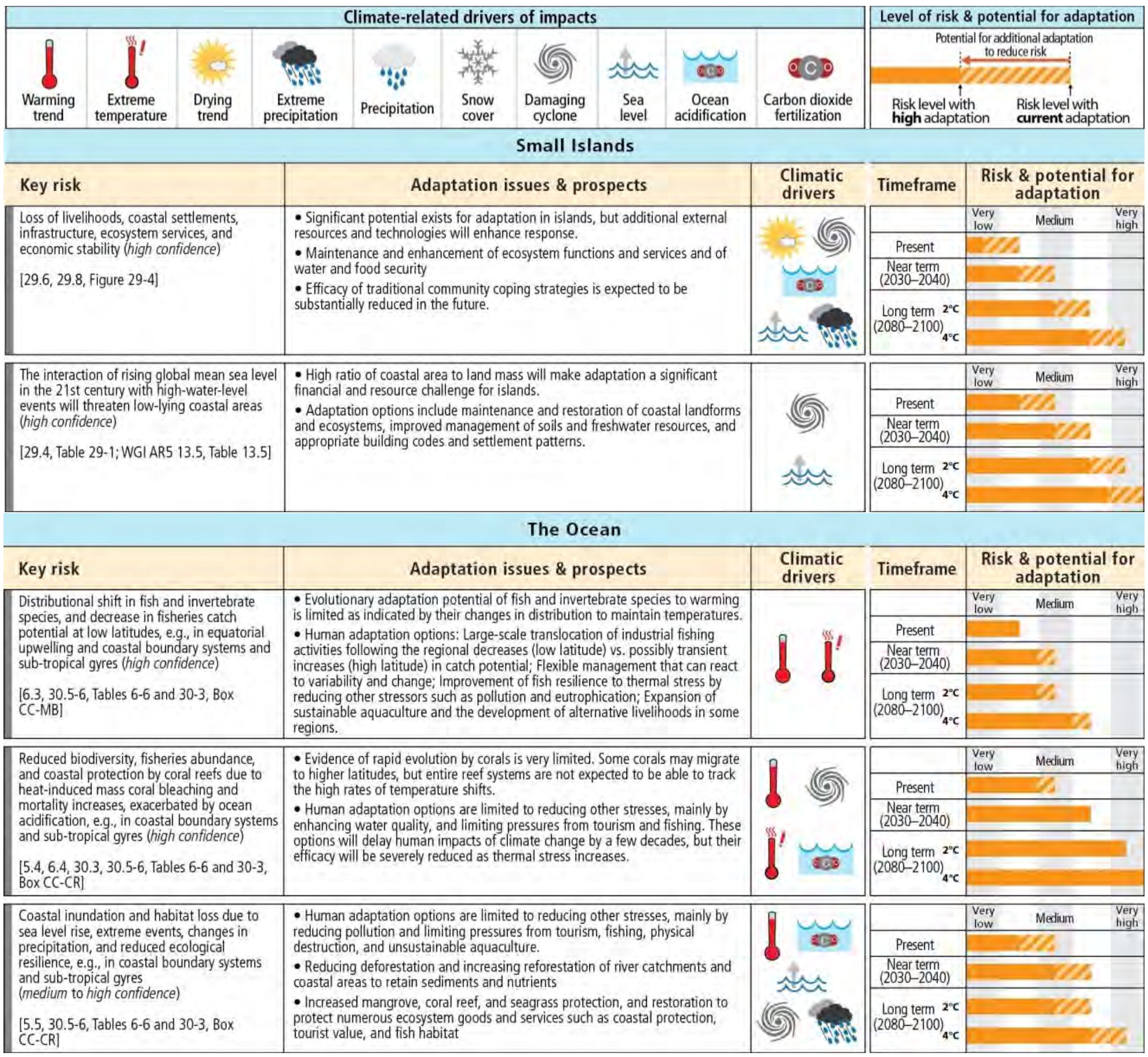


Figure 1.4: Key regional risks from climate change and the potential for reducing risks through adaptation and mitigation for SIDS and the ocean
(Source: IPCC Fifth Assessment Report (AR5) WGII: Summary for Policymakers)

The First National Communication for Trinidad and Tobago in 2001 indicated that climatic change needs to be factored into water management strategies, drought management and flood damage reduction programs. Other vulnerable sectors for which adaptation measures would be required also included coastal resources, agriculture, forestry, health, and food security (Adaptation Learning Mechanism, 2009). Water resource managers would need to consider present and future demand in light of declining rainfall, more frequent and longer dry spell, higher evaporation rates and salinity intrusion. Coral reefs, a high value ecosystem, service for coastal protection and basis for tourism, is at serious risk, with major coral bleaching events correlated to ocean warming in the Caribbean in 1983, 1997, 1998, 2005, 2006, 2009 and 2010. Observations for the region reflect global findings and studies show that Caribbean reefs will continue to be severely degraded in coming decades, based on response of corals to thermal stress and ocean acidification. There is no field evidence to indicate that corals can adapt to unabated thermal stress on decadal timescales (Nurse, 2015).

With regards to the health sector, higher incidences of vector-borne diseases, such as dengue fever, have been occurring since 1970. In December 2013, the first case of the vector-borne disease chikungunya, originating from Africa and Asia, was confirmed in the Caribbean. Over the last two years Trinidad and Tobago has been experiencing an epidemic and the changing climate continues to create conditions for the proliferation of the mosquitoes that carry the disease. Since 1950, there has been an increase in morbidity and mortality from hydro-meteorological events such as floods and storms. Increasing freshwater scarcity and thus sanitation and hygiene has been occurring since 1960. Tourism is already experiencing direct and indirect effects from climate change in the Caribbean. The risks to critical coastal infrastructure and loss of revenue are anticipated to increase from sea level rise and the associated flooding and coastal erosion, as well as the decline of coral reefs.

According to Nurse (2015), climate change will continue to exacerbate existing challenges in the region, as well as trigger new ones. The Caribbean region has demonstrated a clear commitment to achievement of the LTGG, as they are of the belief that there is adequate, credible evidence to justify its pursuit and that delaying mitigation will frustrate achievement of the long-term goal and impose further limits on adaptation.

1.6.3 The Climate Change Data Situation for Trinidad and Tobago

The data production and sharing within Trinidad and Tobago, similar to many developing countries, is plagued with inefficiencies such as data production done in isolation - with a great potential for data duplication and repetition of errors. With regards to spatial data, some of the major challenges being faced are limited, incomplete and/or dated spatial data; lack of data standards; ownership, law and policy issues; and reluctance to share data (Boodoo, 2009). In November, 2014, Trinidad and Tobago launched their council for the development of a National Spatial Data Infrastructure (NSDI).

Based on discussions with Dr. Bheshem Ramlal, chairman of the NSDI Council for Trinidad and Tobago, he indicated that the council was established to ensure and oversee the development and implementation of an integrated information infrastructure that provides geographical and other data to diverse users. It is expected to provide government agencies with access to extensive data and tools to support the decision-making and policy development processes. The operationalized NSDI is also expected to reduce the duplication and therefore the cost of spatial data collected and utilized by ministries and government agencies. Presently, staff recruitment is underway for operationalization of the council.

The Council is mandated to:

- Develop, maintain and support policies such as spatial data protection, spatial data sharing;
- Develop standards such as metadata standards and data quality standards;
- Establish appropriate collaborative mechanisms with organizations participating in the NSDI;
- Identify personnel and training needs of stakeholder organizations;
- Provide data acquisition oversight;
- Provide support on standards and specifications;
- Develop an agreement with tertiary level institutions to establish a NSDI research and innovation centre;
- Work with stakeholder organizations to establish corporate spatial data infrastructure;
- Develop the NSDI clearinghouse or spatial portal;
- Develop and implement a database backup and recovery strategy;
- Develop appropriate geo-services;
- Fulfill the country's international obligations with respect to the provision of spatial data and other information; and
- Develop and maintain a registry of geographic information systems (GIS) professionals in Trinidad and Tobago

Further to this, a National Consultation on Climate Services (NSC) and National Climate Outlook Forum (NCOF) for Trinidad and Tobago was held in May, 2015. The event was hosted by the Trinidad and Tobago Meteorological Services (TTMS) through guidance by the Global Framework for Climate Services (GFCS). GFCS was established to empower society to better manage the risks and opportunities arising from climate variability and change, with the fundamental aim of increasing and improving interactions between climate service providers and those who make use of the services. Trinidad and Tobago recognises that the GFCS is a critical framework that will provide opportunities and information for use in practical climate risk reduction and adaptation needs of the country, as well as, enabling a cooperative arrangement between the Trinidad and Tobago Meteorological Service, government agencies, other key organizations and stakeholders (Trinidad and Tobago Meterological Service, 2015).

The NSC aimed to facilitate dialogue among climate service providers; to review the current climate services available and facilitate dialogue on developing a system for generation and delivery of climate information and services that engages national needs and demands; to discuss the use of climate information in decision making; and to discuss the sustainable implementation of a national framework for climate services in Trinidad and Tobago by focusing on the need for capacity building in climate research, climate observation and monitoring, operational climate information generation, and end-user interaction and engagement. Whereas the NCOF is expected to provide a seasonal outlook to observing the WMO standards tailored towards national requirements; improved communication of climate information to users; improved understanding and interpretation of climate information communicated; and sustainable methodology for developing and providing consensus based seasonal outlooks tailored for particularly vulnerable sectors.

The outcome of such an initiative is in line with the aim of this study and is a prospective undertaking in addressing the key challenges of climate data.

1.7 National Adaptation Plans (NAP) Guidelines[13] for Data

The NAP process aims to reduce vulnerability to the impacts of climate change, by building adaptive capacity, and to facilitate the integration of climate change adaptation into development planning. The technical guidelines of the NAP were developed by the UNFCCC's Least Developed Countries Expert Group (LEG), with inputs and feedback from the Global Environment Facility (GEF) and its agencies, and experts from other organizations, as requested by the Conference of Parties (COP). The NAP focuses on developing countries and least developed countries (LDCs) as the COP recognizes that their climate change risks are magnified and that adaptation planning needs to be addressed in their broader sustainable development planning.

The COP also recognizes that enhanced action on adaptation should be based on and guided by the best available science and, as appropriate, traditional and indigenous knowledge, and by gender-sensitive approaches, with a view to integrating adaptation into relevant social, economic and environmental policies and actions, where appropriate. The plan for each country may differ based on their specific sectoral and national needs and the guidelines are based on lessons learned from countries that are already developing adaptation plans and strategies. In the case of the developing countries, it is expected that plans be put into place to enhance the knowledge base for the long-term NAP process, as their data is limited - both in terms of quantity and quality. Table 1 shows the four elements of the NAP process.

Table 1.1: The four elements of the NAP process

Element D: Reporting, Monitoring and Review	**Element A:** Lay the Groundwork and Address Gaps
Element C: Implementation Strategies	**Element B:** Preparatory Elements

[13] Parts of this section were extracted from the full report, which is available at: <http://unfccc.int/files/adaptation/cancun_adaptation_framework/national_adaptation_plans/application/pdf/naptechguidelines_eng_low_res.pdf>

Considerations for data in the NAP occur mainly in Element B and to a small extent in Element A. Element A, suggests a stocking step that requires identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process. The indicative activities of this step are to:

a. Conduct a stocktaking of on-going and past adaptation activities and their effectiveness;
b. Synthesize available analyses of the current and future climate at the broad national and/or regional level;
c. Conduct a gap analysis to assess strengths and weaknesses regarding the capacity, data and information, and resources required to effectively engage in the NAP process and;
d. Assess potential barriers to the planning, design and implementation of adaptation.

Point b. above allows available systematically observed climate data and their analyses to be identified and aids in determining the gaps in data and information indicated in point c. above. The stocktaking step establishes the knowledge base for developing a NAP, drawing on available data and information. Point b. prevents duplication by identifying where relevant climate models or scenarios already exist. The gap analysis in point c., will identify areas that require strengthening in order for the country to successfully undertake the NAP process. This point allows potential barriers to the design and implementation of adaptation to be identified and addressed.

The long-term goal of the synthesizing exercise would be to arrive at a structured system or database that systematically documents expert knowledge on impacts of climate change in a way that avoids redundant assessments. Global, regional and national assessments are all instrumental in guiding the synthesis of available analyses. The downscaling of climate models is becoming more recommended as they provide additional and more detailed insight on the impacts that may be expected.

Element B aims to prepare countries to undertake an in-depth impact, vulnerability and adaptation assessment. It is designed to involve all stakeholders in preparing a NAP that builds on, and can be integrated into, sectoral, subnational and national plans and strategies. Table 2 outlines the steps and indicative activities involved in Element B, all of which are fed by data. However step 1 (particularly indicative activities a. and b.), derived from systematic observation, provides the foundation for the science that informs the later steps of the NAP process.

Table 1.2: Suggested steps and indicative activities for element B on preparatory elements of the NAP process

Steps	Indicative Activities
1.Analyzing current climate and future climate change scenarios	a. Analyse the current climate to identify trends in variables and indices that could be used to support planning and decision-making b. Characterize broad future climate risks and levels of uncertainty using scenario analysis at the

	national level or as part of a regional analysis including through climate and socioeconomic scenarios c. Communicate projected climate change information to all stakeholders and the public
2.Assessing climate vulnerabilities and identifying adaptation options at sector, subnational, national and other appropriate levels	a. Assess vulnerability to climate change at sector, subnational, national or appropriate levels (by applying applicable frameworks) b. Rank climate change risks and vulnerabilities c. Identify and categorize adaptation options at multiple scales to address priority vulnerabilities
3.Reviewing and appraising adaptation options	a. Appraise individual adaptation options, including economic, ecosystem and social costs and benefits, and possibilities for unintended (positive and negative) impacts of adaptation measures
4.Compiling and communicating national adaptation plans	a. Aggregate sectoral and subnational adaptation priorities into national adaptation plans through stakeholder ranking processes and make the drafts available for review b. Integrate review comments into the national adaptation plans and process endorsement at the national level as defined in the mandate for the NAP process c. Communicate and disseminate the national adaptation plans widely to all stakeholders in the country
5.Integrating climate change adaptation into national and subnational development and sectoral planning	a. Identify opportunities and constraints for integrating climate change into planning b. Build and enhance capacity for integrating climate change into planning c. Facilitate the integration of climate change adaptation into existing national and subnational planning processes

Indicative activity a. of step 1 for Element B forms the basis for understanding trends and patterns from the current and past climate. It requires basic systematic observation of temperature and rainfall data and their subsets, which are currently available at countries' meteorological services. Methods for quality control of station measurements of these two variables are well described in the literature, and several regional and global centres compile and redistribute daily station data. However, there is a known limitation in the lack of maintenance of climate observational networks in developing countries, which continues to hinder the design and implementation of their adaptation measures.

Indicative activity b. goes a step further, to look into medium and long term scenarios from these climate trends and assessments of the probable impact, taking into account both the climate science and socioeconomic aspects. The results of these analyses can inform specific adaptation measures such as management of water flows in dams and protection of forest biodiversity (a project example for Trinidad is outlined in section 4.1.1 of this report). This is being done on both a global and regional scale, where in the case of the regional scale, downscaling exercises are being conducted. Despite advances in the modelling, lack of observed climate data in many developing countries present a considerable challenge to improving the quality of downscaled climate scenarios. Examples of climate models from countries with well-developed national adaptation plans, such as the U.S. and the U.K., are accessible to scientists and regional research centres worldwide to aid in supporting their application in developing countries and in some regions, efforts are under way to build national capacity to run and process regional climate models.

Indicative activity c. deals with the communication aspect of the outcomes from the data observation and analyses in the previous two activities. The process involves informing all stakeholders and this requires customizing the material to each respective target audience from high level policy-makers to the general public. Methods and examples of outreach efforts can be found on the UNFCCC's information network clearinghouse, CC:iNet[14]. A flow diagram showing the guidelines for key aspects of data and SO under the NAP can be found in Appendix B.

1.7.1 Key Messages from the NAP Expo 2015

The third Nap Expo was held in Bonn, Germany during April 2015. It aimed to provide a platform for interactions and exchanges among various countries in the formulation and implementation of the NAP, taking into consideration technical knowledge and best practices. The two day exchange yielded a number of key messages pertaining to data as outlined below:

- Data is the basis for informing climate change studies.
- Many data gaps exist in developing countries, these include:
  - Poor organization of historical records and the need for digitization of such data (indicated by country representatives for Malawi, Maldives and Peru).
  - Insufficient meteorological stations and/ or poorly maintained meteorological stations.
  - Lack of expertise in analysis of climate data (indicated by country representative for Malawi).
  - Lack of inclusion of all stakeholders in the data collection process, including persons responsible for socioeconomic data, which is a very important component that is often overlooked during situation analyses.
  - Lack of sectoral coordination/ duplication of data.
  - Restricted data sharing.
  - Lack of political will and support for efficient data collection strategies.
  - Lack of understanding of the economic value derived from outcomes of data analysis in developing countries.
  - Lack of understanding of integration of indigenous data into national processes.
  - Financial limitations in the form of insufficient funding for data systems, as well as prolonged financial processes that do not align with data implementation plans.

[14] Available at: < http://unfccc.int/cc_inet/cc_inet/items/3514.php>

- There is a need to downscale data to the local level in order to capture better accuracy of the scenarios for some countries.
- Indigenous knowledge is instrumental in addressing data gaps on the ground. United Nations Educational, Scientific and Cultural Organization (UNESCO) is undertaking work in this area and has published case studies that provide an understanding of the needs at the local level. Capacity building of the local people is an important consideration in promoting engagement in this area.
- The communication point in indicative activity 3 of step 1 for Element B was reinforced – The link between data producer and user should be strong and clearly communicated for the data to be meaningful.
- The NAP country examples may want to explore providing best practice examples of data collection and management. The Caribbean Community Climate Change Centre (CCCCC) was highlighted as a good example of a coordinating Climate Change Centre advising the regional subsidiaries with the same goals and securing financial support from international funding bodies. Their data collection and management system is outlined in section 3.1.1.4 below.
- Monitoring and evaluation plans are a critical component and should be considered at the beginning of the NAP process.

Chapter 2: Case Study Approach

2.1 Methodology

The methods used in compiling this case study are as follows:

- Review of the UNFCCC's literature on systematic observation and guidelines for data from the National Adaptation Plans (NAP).
- Research of relevant current local, regional and international literature (reports, presentations, scientific journals, other publications and websites) on the situation for climate change and climate information in SIDS, with a focus on Trinidad and Tobago, including identifying an on-going climate change adaptation programme and its data requirements, as an example.
- Liaisons with relevant local and regional experts on the situation with climate data in the various applicable sectors, including for the local example identified above.
- Compilation of data collected, analysis of findings and recommendations to gaps and/or inefficiencies observed.

2.2 Data Sources

Table 2.1 below outlines the local and regional sources of data for this case study, which were categorized based on type and details of data obtained, contact person(s) (where relevant) and his/her affiliation.

Table 2.1: Primary and secondary data sources for this case study

Data Type	Details	Data Source
Primary Data		
Geospatial data	Information on the local organizations that can provide data relevant to climate studies and information on the status of the NSDI for Trinidad and Tobago.	Dr. Bheshem Ramlal, Head of the Department of Geomatics Engineering and Land Management, the University of the West Indies (UWI)
Weather and climate data	Information on the local meteorological services, the stations that provide climate data and supply global climate databases.	Mrs. Arlene Aaron-Morrison, Climatologist at the Trinidad and Tobago Meteorological Service
Sea level rise data	Information on existing local and regional stations.	Prof. John Agard, Head of the Department of Life Sciences, Faculty of Science and Technology, UWI; and member of the IPCC
Regional data portals	Information on regional climate data and climate projections and processes required in regional downscaling of data.	Timo Baur, Clearinghouse Manager/ Information Systems Advisor, CCCCC
The local example: GoLo CarSce	Information on the project and its sources of data	Prof. John Agard, Team Leader of the GoLo CarSce Project *(secondary data via the project website)*
Secondary Data		
Weather and climate data; Global data portals	Global datasets	Internet search (refer to sections 3.1.1.2 and 3.1.1.4)
Scenario data	Global climate change scenario data	IPCC's Data Distribution Centre website
Socio-economic and sectoral data	Information on the climate data situation for the country and the gaps	Internet search; Country reports
International climate data situation and guidelines	Information on the international standards based on UNFCCC agreements	UNFCCC's website and the NAP Technical Guidelines

Chapter 3: Findings

3.1 General Sources of Climate Data in T&T

Data that pertains to climate change can be derived through scientific systematic observation as well as through socio-economic analyses. Although systematic observation currently forms to basis of climate change actions, socio-economic studies add another dimension to findings that allows for a more holistic understanding of the situation, the impacts that will be faced and more effective management strategies to cope.

3.1.1 Systematic Observation

Typically the systematic sources of climate data are derived from five sources: geospatial data, weather and climate data, sea level rise data and scenarios, information portals and climate change scenarios. These sources of data for Trinidad and Tobago are outlined in the next sections.

3.1.1.1 Geospatial Data

This includes to administrative lands, boundaries; topography; land use, land cover, slope, soils and basins. The sources of these spatial datasets, both historical and current and both digital and in hardcopy formats can be found locally at:

i. The Lands and Surveys Division
ii. Town and Country Planning Division
iii. Soils Division, Ministry of Food Production
iv. The Water Resources Agency

3.1.1.2 Weather and Climate Data

The Trinidad and Tobago Meteorological Services (TTMS) is responsible for weather forecasting and issuing of early warnings to the country. They provide essential climate variables such as rainfall, temperature, relative humidly, wind direction and wind speed to GCOS and other climate data collection bodies. TTMS currently own and operate two (2) synoptic weather stations (manned stations) which are also climatological stations. These stations are located in Piarco, Trinidad and Crown Point, Tobago. Data from Piarco, Trinidad date from 1946 to present and data from Crown Point, Tobago date from 1968 to present. The TTMS also own and maintain seven (7) automatic weather stations (AWS) all located in Trinidad. These are Brasso Venado, Caroni, Centeno, Chatham, El Reposo, Penal and Guayaguayare. Figure 3.1 shows locations of all weather stations.

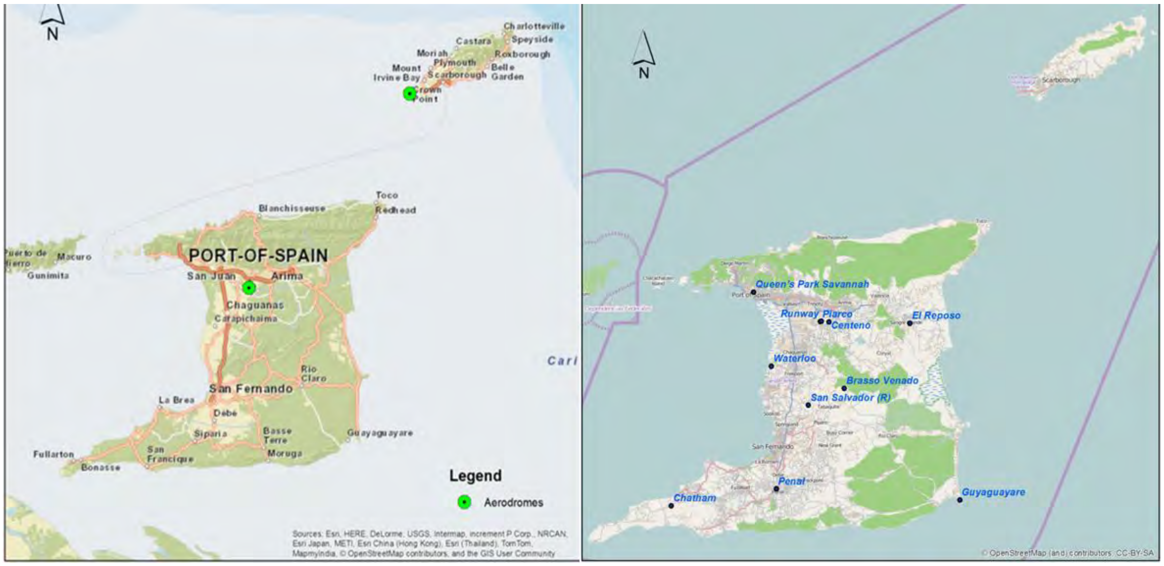


Figure 3.1: Location of synoptic stations and AWS stations
(*Source: TTMS*)

However, only data from the synoptic weather stations supplies the global databases of WMO and GCOS, due to lack of resources allocated for sufficient maintenance of the AWS. The Water and Sewerage Authority of Trinidad and Tobago (WASA) own and maintain approximately seventy-six (76) rain gauges which are utilized for climatological forecasts and research (refer to figure 3.2).

Figure 3.2: Location of rain gauges
(*Source: TTMS*)

Portals containing global datasets on weather and climate can be found in the global portals section of 3.1.1.4 (x. and xi.).

3.1.1.3 Sea Level Rise Data and Scenarios

Sea level rise (SLR) monitors were installed along the coastline of Trinidad and Tobago, at the two lowest lying areas, the Caroni Swamp and the Nariva Swamp, by the Caribbean Community Climate Change Centre (CCCCC) approximately 10 years ago. Due to marked differences in the station data, which are of marginal distances apart, the data is deemed unreliable. This may be attributed to lack of maintenance of the instruments as well as the inability of the instrument to measure land subsistence. Alternatively, considerations are being made for use of the sea level rise data generated by a high-tech station installed by the National Oceanic and Atmospheric Administration (NOAA), off the coast of Puerto Rico. SLR scenarios based on larger scale assessments and downscaling of the models can be found through portals as identified in the next section 3.1.1.4.

3.1.1.4 Portals

Global Portals

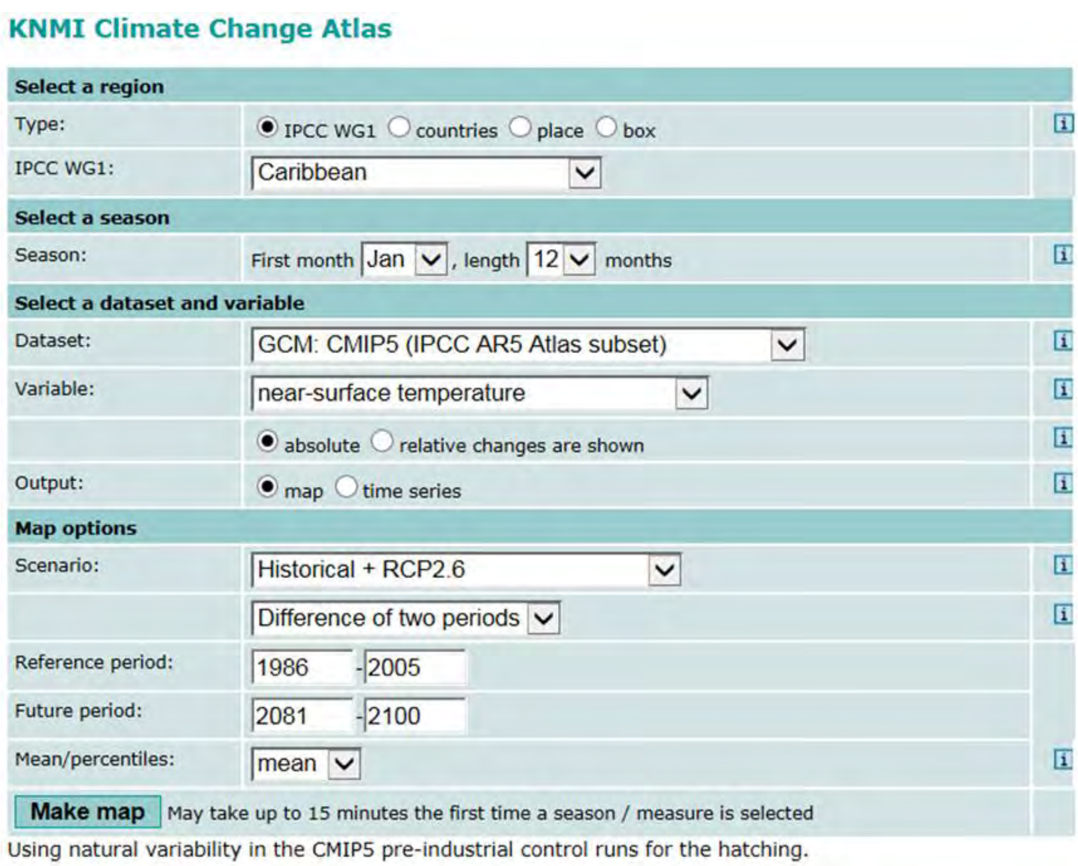
A number of global climate data portals, through which regional data can be extracted exists, as is outline from i. – xi. below. Weather and climate data (as outlined in section 3.1.1.2 above) can specifically be obtained from the portals identified at x. and xi. Most of the datasets provided by these portals are available at no cost for academic and other non-commercial use, in some cases they are registered under open database licenses, which allows for all uses provided that the sources are acknowledged.

i. The Global Observing Systems Information Center (GOSIC)[15]:
The GOSIC provides access to data, metadata and information from GCOS and partner observing systems. The page provides an overview of all GCOS-relevant network components and systems, separated by domains.

ii. IPCC Data Distribution Centre (DDC)[16]:
The DDC provides climate and environmental data, as well as non-systematic socio-economic data globally and region specific, in the form of both historical and projection data. Technical guidelines on the selection and use of different types of data and scenarios in research and assessment are also provided[17].

[15] Available at: <http://www.wmo.int/pages/prog/gcos/index.php?name=ObservingSystemsandData>
[16] Available at: <http://www.ipcc-data.org/sim/gcm_monthly/SRES_AR4/index.html>
[17] Technical guidelines, fact sheets and other supporting material available at: <http://www.ipcc-data.org/guidelines/index.html>

iii. Kononklijk Netherlands Meteorological Institute (KNMI) Climate Explorer[18]: The Climate Explorer is a web application to analysis climate data statistically From its inception in 1999 to now, it has grown over the years to more than 1TB of climate data and dozens of analysis tools. It is now part of the WMO Regional Climate Centre at KNMI, together with European Climate Assessment & Dataset (ECA&D) project. It provides data and maps on climate variables including models from IPCC AR5 for specific countries. Figure 3.3 shows a screen-shot of the web application being used to project near-surface temperature for the Caribbean region from 2081-2100, using RCP2.6. Figure 3.4 and 3.5 shows the map projections for near-surface temperature using RCP 4.5 and precipitation using RCP 2.6, for the Caribbean region during 2081-2100. These figures show that although projections exist for specific regions, the resolution is not of a high quality and provides little detail.



18 Available at: <http://climexp.knmi.nl/plot_atlas_form.py?id=someone@somewhere>

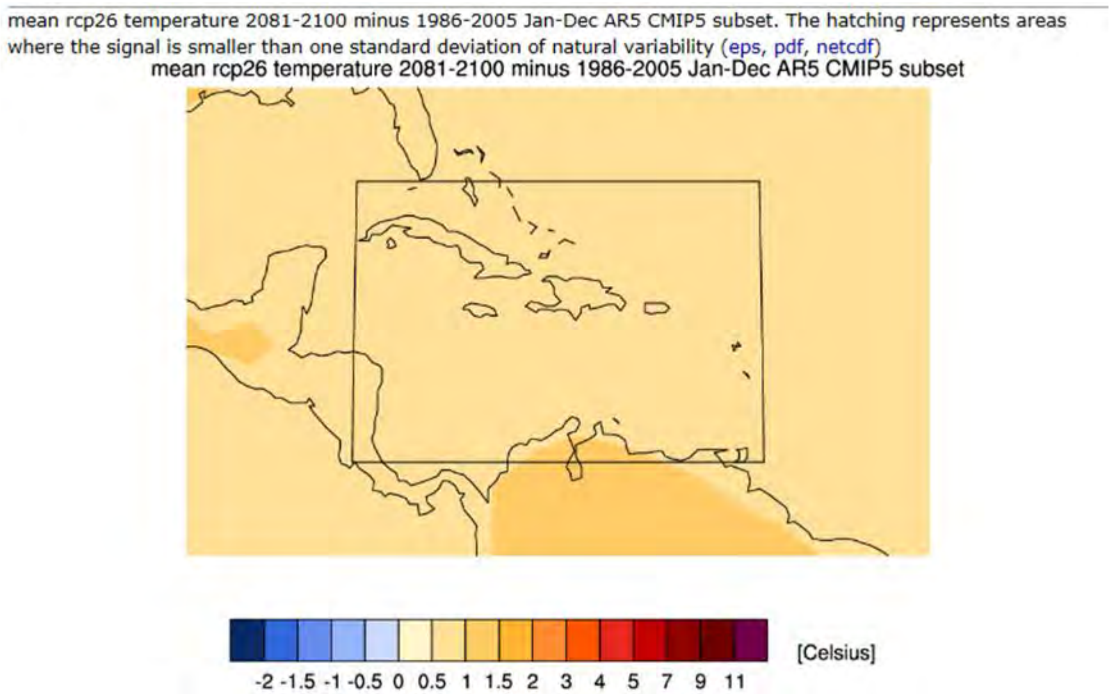


Figure 3.3: Screen-shot of web application to project near-surface temperature for the Caribbean region from 2081-2100, using RCP2.6
(Source: KMNI Climate Explorer)

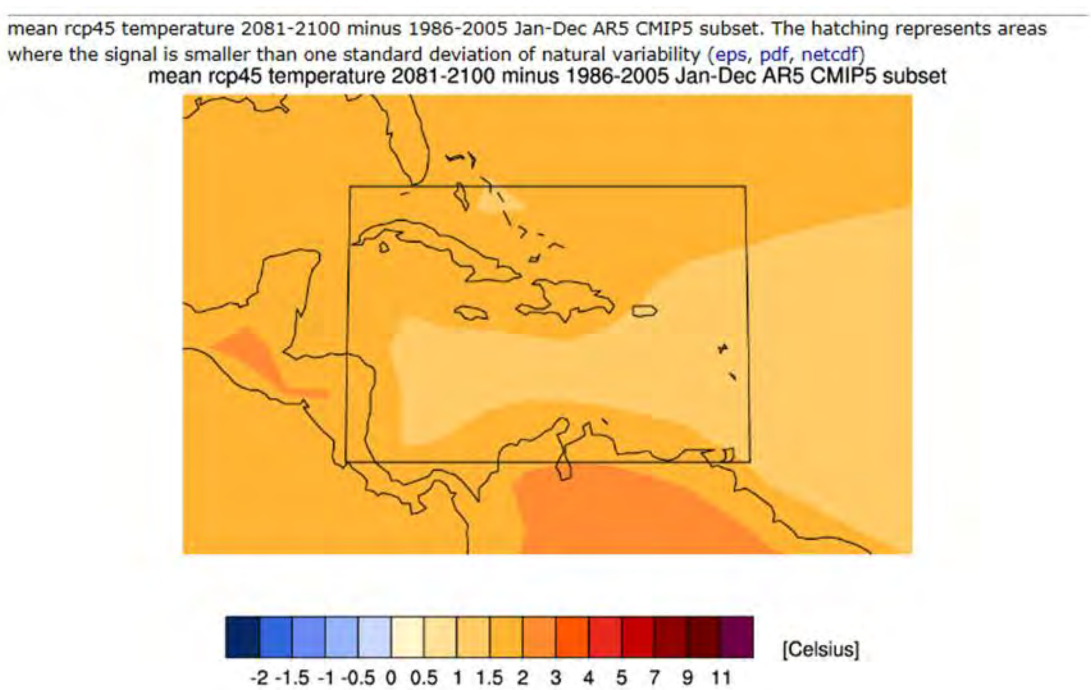


Figure 3.4: Map projection for near-surface temperature for the Caribbean region from 2081-2100, using RCP 4.5
(Source: KMNI Climate Explorer)

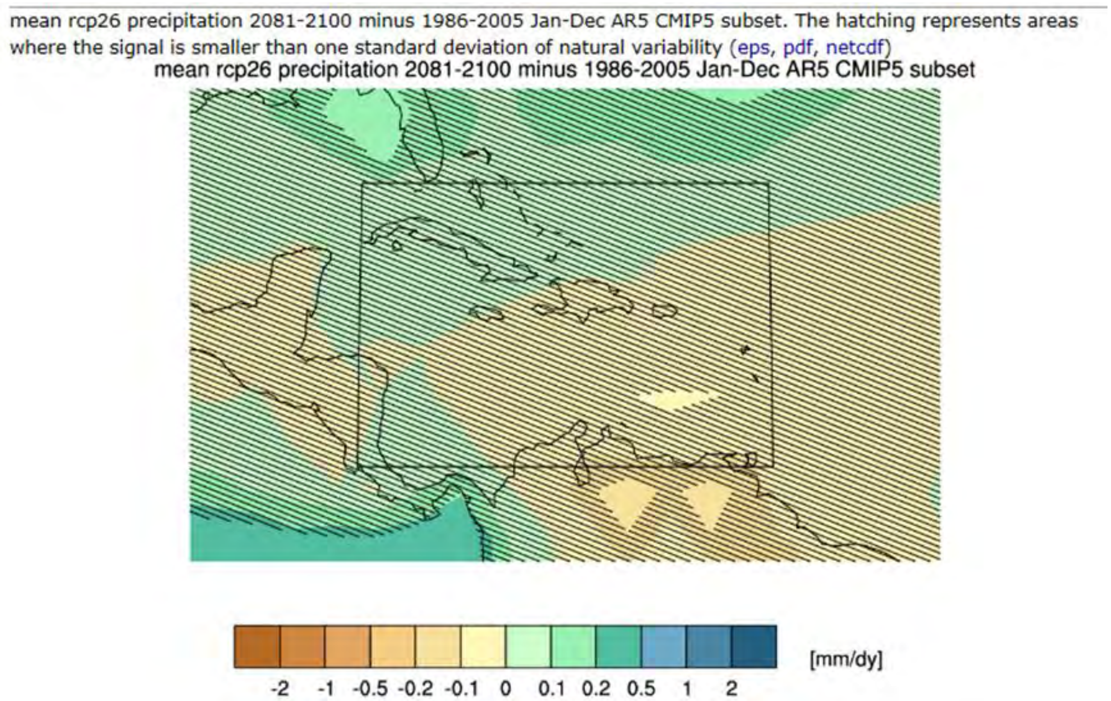


Figure 3.5: Map projection for precipitation for the Caribbean region from 2081-2100, using RCP 2.6 *(Source: KMNI Climate Explorer)*

iv. Global Historical Climatology Network (GHCN)[19]:
Administered by NOAA, GHCN is the official archive dataset, composed of climate summaries from land surface stations across the globe. The data comprises more than 20 sources, contains historical data as far back as 175 years and has been subjected to a common suite of quality assurance reviews.

v. The World Bank Group – Climate Change Knowledge Portal[20]:
In an effort to serve as a 'one-stop-shop' for climate-related information, data, and tools, the World Bank created the Climate Change Knowledge Portal (CCKP), which is supported by the Global Facility for Disaster Reduction and Recovery and others. The portal provides data on climate and non-systematic data on impacts and vulnerabilities for various countries worldwide. It also directs users to other external links with climate change relevant data.

vi. United Nations Development Programme (UNDP) Climate Change Country Profile – Trinidad and Tobago[21]:
These country profiles were developed to address the climate change information gap in many developing countries by making use of existing climate

[19] Available at: < https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/global-historical-climatology-network-ghcn>
[20] Available at: <http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Latin America&ThisCCode=TTO> and the user's guide can be found at: <http://sdwebx.worldbank.org/climateportal/index.cfm?page=resource#user_guide>
[21] Available at: <http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/>

data to generate country-level data plots from the most up-to-date climate observations and the multi-model projections from the World Climate Research Programme (WCRP) Coupled Model Intercomparison Project (CMIP)[22] 3 archive (Meehl et al., 2007) (as cited in McSweeney, C.,New M. and Lizcano G., 2010). Since CMIP3, two more recent versions have been developed – CMIP5 and CMIP 6, which serve the IPCC in their assessment reports. The draft UNDP Climate Change Country Profile Documentation describes the contents and method used to construct the UNDP climate change country profiles[23].

vii. Coordinated Regional Climate Downscaling Experiment (CORDEX)[24]:
CORDEX, also a product of the WCRP, is an internationally coordinated framework that aims to advance and coordinate the science and application of regional climate downscaling through global partnerships. Regional downscaling is rapidly becoming an important consideration is filling the data gap, as it addresses further detail on climate conditions and provides complementary means for the study and assessment of regional-scale climate change and subsequently climate impacts. The wealth of regional climate scenarios however, is still predominantly directly based on global climate model outputs.

viii. Downscaled GCM Data Portal[25]:
The datasets contained in this website are part of the International Centre for Tropical Agriculture (CIAT) and the Consultative Group for International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS). It is used in context of changing climate on agriculture and food security. The data distributed here are in ARC GRID, and ARC ASCII format, in decimal degrees and datum WGS84. CCAFS and its partners have processed this data to provide seamless continuous future climate surfaces.

ix. IRI/LDEO Climate Data Library[26]:
The IRI Data Library is a powerful online data repository and analysis tool that allows a user to view, analyze, and download hundreds of terabytes of climate-related global data through a standard web browser.

x. WorldClim[27]
This portal contains a set of global weather and climate layers (grids) with a spatial resolution of about 1 square kilometre. The data can be used for mapping and spatial modelling in a GIS.

xi. University of East Anglia – Climate Research Unit[28]

[22] Further detail can be found at: < http://wcrp-climate.org/wgcm-cmip/about-cmip>
[23] Available at: <http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDPCCCP_documentation.pdf>
[24] Available at: <http://world climate research programme-cordex.ipsl.jussieu.fr/>
[25] Available at: <http://www.ccafs-climate.org/>
[26] Available at: <http://iridl.ldeo.columbia.edu/>
[27] Available at: < http://www.worldclim.org/>

The data section of this unit contains weather and climate datasets which are available via an online portal. Some of the datasets however must be requested through the unit's personnel.

Regional Portal

The Caribbean Community Climate Change Centre (CCCCC) coordinates the Caribbean region's response to climate change. It provides climate change-related policy advice and guidelines to the Caribbean Community (CARICOM) Member States through the CARICOM Secretariat and to the UK Caribbean Overseas Territories and is the archive and clearing house for regional climate change data and documentation (CCCCC, 2015).

In conducting the research for this case study, Mr. Timo Baur, Clearinghouse Manager/ Information Systems Advisor of the CCCCC, outlined the Centre's available data, their sources, their links with other regional and international data intuitions and the gaps that currently exist within the data. The CCCCC has projected temperature and rainfall data from various downscaled models that covers Trinidad and Tobago, as well as the region, until 2100. These projections were created using the PRECIS (Providing REgional Climates for Impacts Studies) downscaling system of the UK Met Office's Hadley Centre, which is fed by data from the ECHAM5 Global Climate Model and the ERA-Interim. ECHAM is a Global Climate Model developed by the Max Planck Institute for Meteorology and has been the basis of many publications, including the IPCC Assessment Reports. ERA-Interim is a global reanalysis of recorded climate observations over the past 3.5 decades, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). The methodology follows the international best practices for climate data and applies the same methods and datasets for the modelling used by the IPCC.

The climate modelling group that creates the projections is regionally supported and to an extent also coordinated by CCCCC. The group is now also working on higher resolution modelling based on the newer Weather Research and Forecasting (WRF) Model[29] that supports the analysis of representative concentration pathway (RCP) scenarios adopted by the IPCC for its Fifth Assessment Report (AR5) in 2014. The modelling group is also involved in relevant international global projects such as CORDEX (Coordinated Regional Climate Downscaling Experiment), which as described in vii. of Global Portals above, is an internationally coordinated framework that produces an improved generation of regional climate change projections globally for input into impact and adaptation studies within the AR5 timeline and to the climate community beyond the AR5. According to Teichmann (2015), CORDEX's vision and goals are to:

- To better understand relevant regional/local climate phenomena, their variability and changes, through downscaling.
- To evaluate and improve regional climate downscaling models and techniques.

[28] Available at: <http://www.cru.uea.ac.uk/data>
[29] The WRF Model is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs.

- To produce coordinated sets of regional downscaled projections worldwide.
- To foster communication and knowledge exchange with users of regional climate information.

Further to this, the CCCCC is facilitating international research collaboration of the modelling group for enhancement of data quality. An example of this is through the Caribbean Weather Impacts Group (CARIWIG) project that is being conducted in partnerships with U.K. research institutes specializing in the management of a range of hazards and impacts. The project aims to serve the Caribbean's water, agriculture and coastal resource sectors through reliable access to unbiased, locally-relevant climate change information in a manner that complements their planning cycles.

Presently, general models that are circulated globally are of around 300 km^2 resolution. This poses a significant issue in the Caribbean, as this resolution sometimes covers entire islands, thereby being unable to provide detail that could be of any use in climate change assessments. The CCCCC's website via their Clearinghouse provides data in a 50 km^2 resolution. Figure 3.6 and 3.7 show sample model projections for mean surface temperature and total precipitation rate in Trinidad and Tobago using this resolution. The two formats of data projections available at the Clearinghouse are:

- ECHAM4 (1991-2100) data for the emission scenarios A2 and B2
- HadAM3P (2010-2100, with 2010-2069 pattern scaled)

For comparison, the global model projection from KMNI for near-surface temperature for Trinidad and Tobago from 2081-2100 is shown figure 3.8. The disparity in detail can be observed, with the global model not have sufficient resolution to offer any detail for the islands.

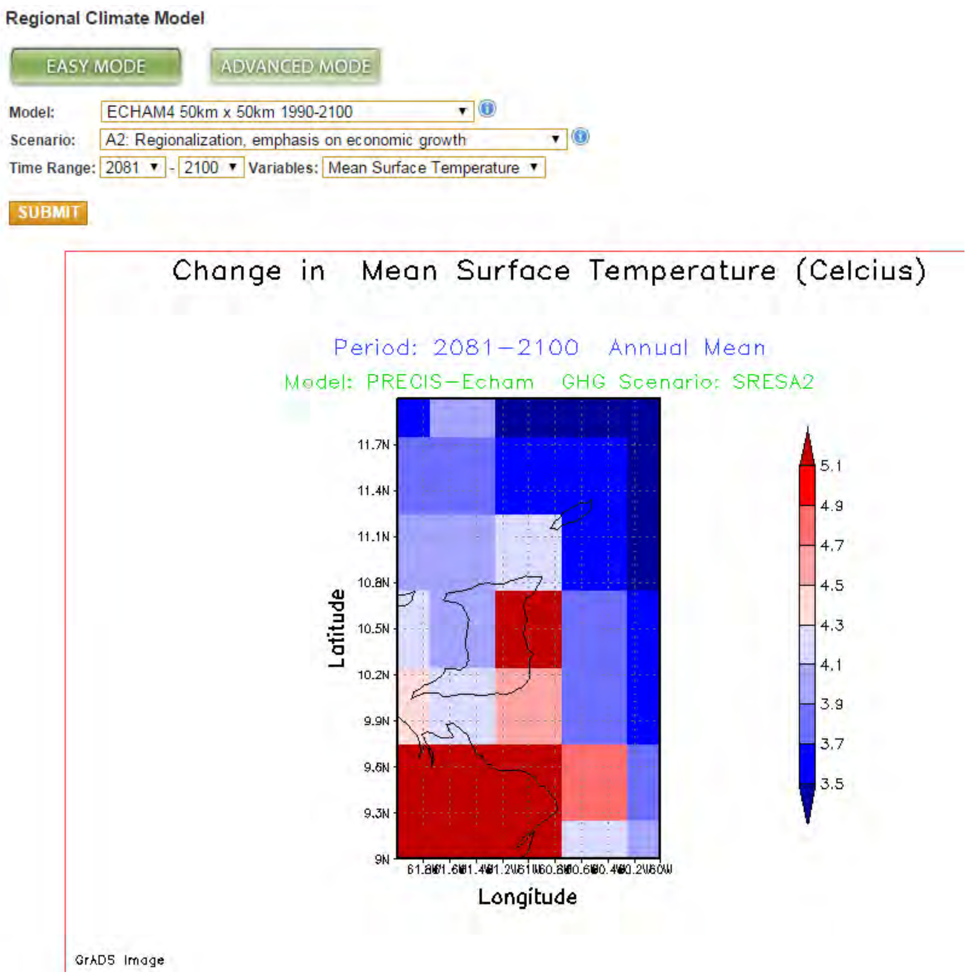


Figure 3.6: Screen shot of the CCCCC's climate model of mean surface temperature for Trinidad and Tobago, from 2085-2100, using the ECHAM4 model (scenario A2)
(Source: CCCCC Clearinghouse)

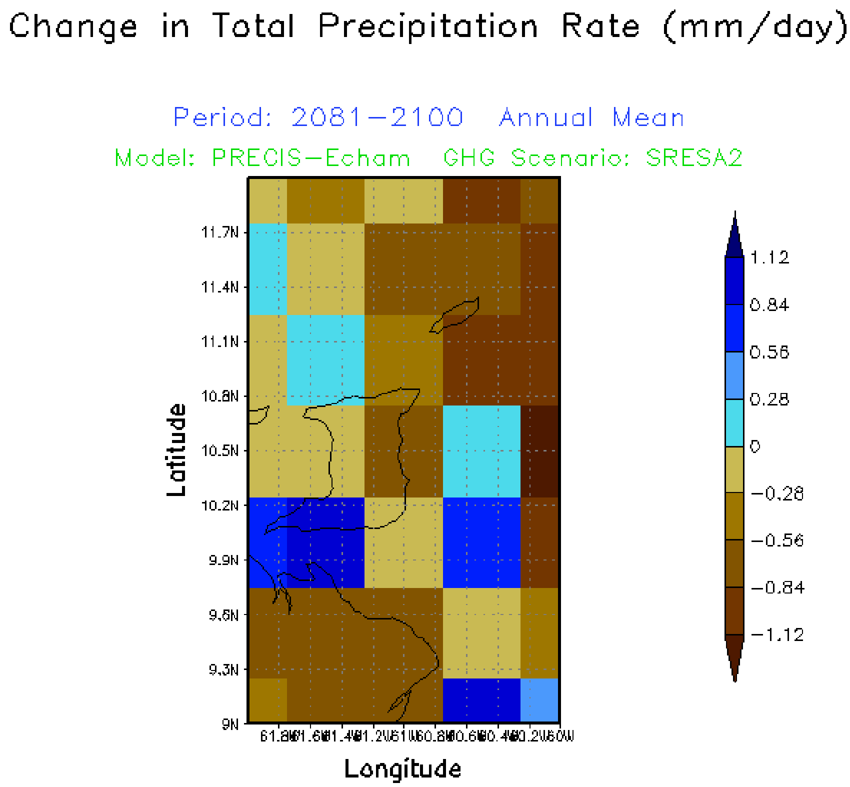


Figure 3.7: The CCCCC's climate model of total precipitation rate for Trinidad and Tobago, from 2081 – 2100, using the ECHAM4 model (scenario A2)
(*Source: CCCCC Clearinghouse*)

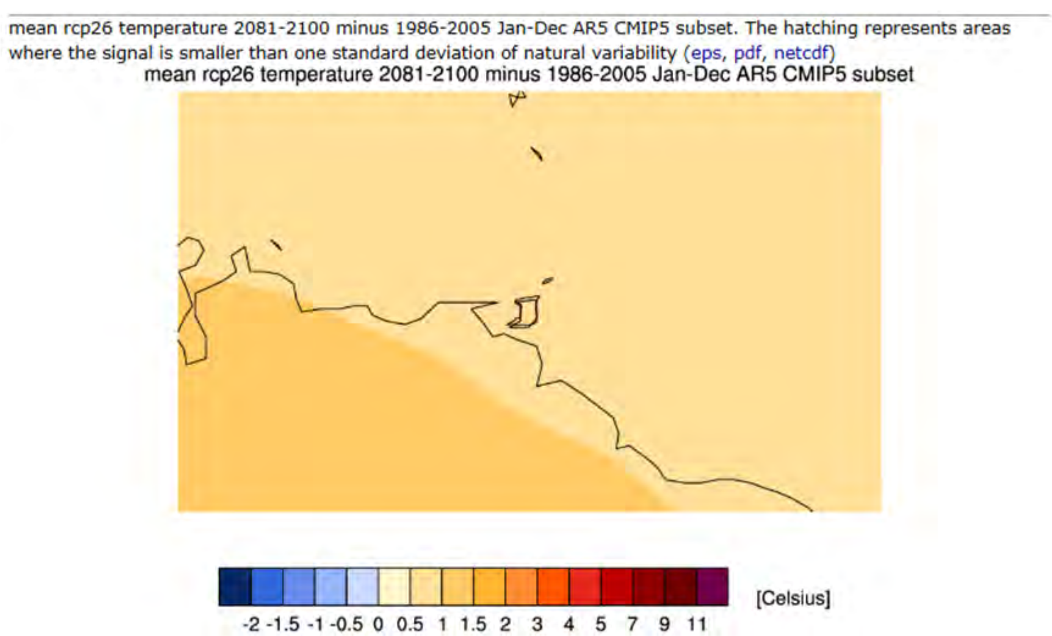


Figure 3.8: KMNI's climate model for near-surface temperature for Trinidad and Tobago from 2081-2100, using RCP 2.6
(Source: KMNI Climate Explorer)

In order to develop impact models, details are needed from even higher resolutions, ranging from 1 - 10 km. For newer studies, it is recommended that the newer ECHAM5 and Hadley Centre in a 25 x 25 km resolution are used. The data is available for online access through the CCCCC's new CARIWIG tool[30], which was launched in June 2015. The CARIWIG tool also provides a stochastic weather generator that allows for more accurate projections for certain locations where historical weather station data is available and will be used for the CCCCC's adaptation studies. The ECHAM5 projection data in a 25 x 25 km resolution can also be provided by the Centre, in an Excel format only. Additionally being planned are projects in partnership with universities in the U.S. that strive to increase the resolution of the models to 3 km.

According to Mr. Baur, the region traditionally has large data gaps when it comes to observed data, particularly in the area of hydro-meteorological data, but also when it comes to other environmental data. This is grounded in the ways the national governments and their departments are funding, managing, preserving and disseminating their data collection.

When it comes to longer term climate analysis, much of the existing longer term data is on paper in archives in the region and in the U.K., and has not been digitized yet. Large parts of what has is available to the meteorological services of individual countries, have not been shared widely with international public databases such as the Global Historical Climate Network (GHCN), which are datasets used by IPCC. This is because there is a conflict on whether raw data that is expensive to obtain should be given away freely or sold. The cost recovery makes sense for meteorological services that normally operate under a limited budget as they are not given priority by Caribbean governments, but the argument remains that the operations are funded by tax payers' dollars, so the public should be privy to the data. However, the meteorological services allow public sharing of the data's products, such as monthly averages, which provide an opportunity to create products that can fill gaps and update the GHCN.

GCOS has very high requirements on the temporal coverage and quality of the data, and the standard of operations of individual weather stations. Therefore, the Caribbean`s contribution to this has so far mostly been from weather stations located at airports that are well funded and operated. Again, there seems to be an issue with funding the maintenance and longer term operation of weather stations that are not national top-priorities. However, as national and regional observation networks are expanding, the future may bring a few more stations that may contribute to this system.

This data situation influences the coverage of datasets, such as the long-term Climate Research Unit (CRU[31]) Global Dataset that is used as an input to the CARIWIG weather generator, as well as IPCC assessments. The data situation on the ground also influences the coverage of the ERA-Interim dataset, which is being used as an input to most climate modelling activities. However, ERA-Interim uses available satellite data that seems to

[30] Available at: < http://cariwig.caribbeanclimate.bz/>

[31] The CRU Global Climate Dataset, available through the IPCC DDC, consists of a multi-variate 0.5º latitude by 0.5º longitude resolution mean monthly climatology for global land areas, excluding Antarctica.

cover the region for recent decades. Ground proofing this data would of course further enhance the quality of the ERA-Interim dataset and therefore could enhance the quality of the climate modelling data.

3.1.1.5 Scenario data

The methods for developing and applying climate change scenarios are the focus of an IPCC task group, the Task Group on Data and Scenario Support for Impact and Climate Analysis (TGCIA), and recommended methods and global scenarios data are maintained on the IPCC Data Distribution Centre website[32]. The work of the IPCC is considered to be among the most comprehensive, with inputs form hundreds of scientists. Their DDC provides climate, socio-economic and environmental data, both from the past and also in scenarios projected into the future, as well as the technical guidelines on the selection and use of different types of data and scenarios in research and assessment. While designed primarily for climate change researchers, the DDC can also be used by educators, governmental and non-governmental organizations and the general public. More localized scenario data could be obtained through the CCCCC as outlined in the regional portal above at 3.1.1.4.

3.1.2 Socio-Economic Data

Population, economic development, technology and natural resources are the socio-economic data required for use in climate impact assessments. This data characterizes the vulnerability and adaptive capacity of social and economic systems from climate change for the different regions and together with environmental data, allows for a more complete assessment. Additionally, socio-economic data provides an understanding of key relationships among factors that drive future emissions, with the major driving force being human economic activity.

In 2014, a comprehensive study was undertaken by the Inter-American Development Bank (IDB), entitled “Understanding the Economics of Climate Adaptation in Trinidad and Tobago”. The report presented the potential hazards due to climate change (refer to Appendix C), calculated the economic effects of climate change in Trinidad and Tobago, proposed actions to mitigate the losses caused by climate change and analyzed their economic costs and benefits.

The economic costs were calculated by estimating the cost of implementing each measure and the economic benefits were calculated based on the probability of the natural hazards occurring, their expected damages and the impact of the measures in mitigating the damages. Although in most cases, several benefits were calculated for each measure, the lack of environmental and social information specific to Trinidad and Tobago resulted in the inability to calculate some benefits to society. In these cases the benefits are expected

[32] Available at: < http://www.ipcc-data.org/>

to be greater than the study indicates, particular as all benefits were not able to be monetized.

The study required historical and current data on systematic observations for climate, as well as socio-economic demographic and economic data. Demographic data on the population, density and settlement patterns as well as data on the location of important infrastructure were essential in determining vulnerability and the value of assets at risk of these hazards. And economic data was required to aid in estimating the value at risk and the economic costs of climate change. The quantification of costs and benefits of the adaptation measure also required data on economic variables. The sources and availability of the socio-economic data required to undertake such an analysis are outlined in table 3.1 below.

Table 3.1: Socio-economic data used in undertaking the study on "Understanding the Economics of Climate Adaptation in Trinidad and Tobago"

Variables	Data Source(s)	Availability
Demographic Data		
Population by parish	Central Statistical Office	Available
Density by parish	Central Statistical Office	Available
Economic Data		
Gross Domestic Product (GDP)	Central Statistical Office; Central Bank	Available
Sector's share of GDP	Central Bank	Available
Inflation rate	Central Statistical Office; Central Bank	Available
Exchange rate	Central Bank	Available
Production in each sector	Government of the Republic of Trinidad and Tobago (GORTT) Ministries	Available
Economic loss to the economy from extreme weather events	International Emergency Disasters Database	Available
Economic loss by sector from extreme weather events	GORTT Ministries	Unavailable
GIS maps of location of major infrastructure	Ministry of Planning and the Economy	Unknown

The IPCC has published a set of socio-economic baseline statistics for 195 countries that are representative of the early to mid-1990s. The data was collated from a variety of sources, including the World Bank, United Nations Environment Programme (UNEP) and Food and Agriculture Organization of the United Nations (FAO) and they comprise a range of factors. It can be found on their Data Distribution Centre (DDC) in seven (7) categories: population and human development; economic conditions; land cover/ land use; water; agriculture/ food; energy and biodiversity[33]. It should be noted however, that their socio-economic data is comprised of selected summary data and for more detailed

[33] Data is available at: <http://sedac.ipcc-data.org/ddc/>

information or higher resolution data for Trinidad and Tobago, the country offices outlined in table 3.1 above should be contacted.

3.2 National and Sectoral Climate Data Gaps

The main sectors within Trinidad and Tobago that will be affected by climate change are agriculture, health, human settlements, coastal zones, water resources, energy (Inter-American Development Bank, 2014) (refer to Appendix C).

According to the 2013 Second National Communications of the Republic of Trinidad and Tobago under the UNFCCC, comprehensive vulnerability and adaptation analyses were challenged by the lack of appropriate data to facilitate adequate modelling with the one exception being health. The report noted the following actions for improving and understanding scientific information and capabilities at the local level:

- Building and enhancing scientific and technological capabilities, inter alia, through continued support to the IPCC for the exchange of scientific data and information;
- Enhancing the implementations of national, regional and international strategies to monitor the earth's atmosphere, land and oceans by improving monitoring stations; and
- Improving techniques and methodologies for assessing the effects of climate change, and encouraging the continued assessment of those adverse effects by the IPCC.

The report notes two vulnerable areas where data gaps exist as biodiversity and marine and coastal resources. The biodiversity action proposed is promotion of practical measures for access to results and benefits arising out of biotechnologies based upon genetic resources, in accordance with Articles 15 and 19 of the Convention including through enhanced scientific and technical co-operation on biotechnology and biosafety. This includes the exchange of experts, training human resources and developing research-oriented institutional capacities.

The marine and coastal resources action proposed is improvement of the scientific understanding and assessment of these ecosystems as a fundamental basis for sound decision marking, through actions at all levels to, inter alia, increase scientific and technical collaboration. This includes integrated assessment at the global and regional levels, for the conservation and management of living and non-living marine resources, and expanding ocean-observing capabilities for the timely prediction and assessment of the state of the marine environment. The report also highlighted data gaps in accessing relevant information for the country's GHG gas inventory due to data being unavailable, outdated or incompatible. The sectors where the GHG gas inventory data gaps exist include the energy, waste, industrial processes, agriculture, land use, land use change and forestry sectors[34] (refer to Appendix D).

[34] Refer to pg 50 – 53: <http://unfccc.int/resource/docs/natc/ttonc2.pdf>

Chapter 4 - Local Climate Change Adaptation Project Example

4.1 Overview of Global to Local Climate Change Adaptation and Mitigation Scenarios (GoLo CarSce)[35]

GoLo CarSce aims to provide a better understanding and management of climate change effects on SIDS within the Caribbean region, through the provision of knowledge, intended to improve resilience and build adaptive capacity towards promoting more sustainable forms of development and livelihoods.

The project was proposed by the African, Caribbean and Pacific Group of States (ACP) Caribbean and Pacific Research Programme for Sustainable Development and is currently being executed over a three-year period, by the Department of Life Sciences, UWI, St Augustine Campus in association with 6 regional partners: UWI Mona; UWI Cavehill's Centre for Resource Management and Environmental Studies; the Cropper Foundation; the Caribbean Agricultural Research and Development Institute (CARDI); and one international partner, the Stockholm Environment Institute.

It is designed to improve the scientific understanding of the effects of climate change on the ecological, social, political and economic systems of Caribbean SIDS, through the development of a set of locally-relevant, socio-economic scenarios for the Caribbean which:

- are being designed within the context and framework of Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5);
- make use of four new Representative Concentration Pathways (RCPs) of the IPCC (refer to Appendix E); and
- will apply cutting edge technologies and tools that analyze climate data, in order to present the most comprehensive and scientifically credible data and projections about the effects of climate change within the Caribbean Region in the medium to long-term (2035 and 2100).

The primary goals of this project are:

<u>At the Regional and National Levels within the Caribbean</u> -

i. To offer the socio-economic scenarios to Caribbean decision-makers in order to demonstrate the cost of inaction and to provide them with a menu of response options that could help to support and enhance decision-making in the region, as it relates to climate change adaptation and sustainable development (including sustainable livelihoods and poverty reduction);

[35] Parts of this section were extracted from the official website, which is available at: <www.golocarse.org>

ii. To provide an opportunity for building the capacity of scientists, researchers and decision-makers within the Caribbean region specifically related to the development and application of climate change socio-economic scenarios; and
iii. To develop stronger bases for economic diversification options that will result in the improved quality of life for Caribbean citizens.

<u>At a Global Level</u> -

i. To make the Caribbean socio-economic scenarios available for use by the scientists of IPCC so that the regional and sub-regional perspectives and considerations which are generated on account of this action could be used to enrich global climate change scenarios and datasets;
ii. To use the experience gained through this action to develop a set of guidelines for downscaling climate change at the sub-global levels (regional, sub-regional, national and sub-national) that could help bring greater consistency to climate change downscaling methods and approaches around the world.

Basic findings from scenarios developed thus far:

- Temperatures of over 1.5^{o}C will impact SIDS considerably.
- All regional models indicate a decrease in precipitation – indicating a need to develop drought resistance species of crops.
- The timeframe between extreme events are getting smaller.

4.1.1 Example for Forest Biodiversity Modelling in Trinidad for Climate Adaptation

This GoLo CarSce project component aims to generate maps indicating the most suitable distribution of High Conservation Value (HCV) species under future climatic conditions in order to determine future effectiveness of Protected Area Networks (PAN). The Caribbean islands rely on their natural resources such as forests, for a number of goods and services. In Trinidad, the forests play a crucial role in the island's sustainability. There are homes to a wide range to important flora and fauna, including endemic species; provide watershed services and help to regulate the climate. Climate change has the potential to adversely affect these species, with HCV being the most vulnerable and this exercise allows for consideration of adaptation strategies.

The methodology at present involves the collection and collation of rainfall and temperature data across the island and the development of a GIS database with soils, elevation and slope data, which are to be used in the model generation. The next activities include the collation of vegetation occurrence data; multivariate analyses on vegetation composition; map generation of vegetation distribution patterns and development of criteria for categorization of HCV species within Trinidad. And the final steps will include development of climate parameters to be used in the modelling analyses; generation, testing and validation of models for individual species; construction of change maps for individual species; construction of collective change maps and an overlay analysis of change maps with existing PAN for verification of their effectiveness under present and future conditions. This final analysis, when done for both individual and collective (from combined groups of species) change maps, will promote conservation of both individual species as well as entire groups of HCV species. Figure 4.1 shows a preliminary modelling analysis for 12 HCV species, which indicate that while present climate conditions allow a relatively high percentage of these species to exist at across the northern and western parts of Trinidad; future climate conditions may result in a drastic reduction of this percentage, with the southern part of the island is projected to contain the highest numbers of these HCV species

The outcomes of this analysis would provide for better design and management of PAN in order to maintain ecosystem health in light of climate change. Through presentation to policymakers, it is anticipated that the socio-economic implications would invoke policy changes to support more effective forest management.

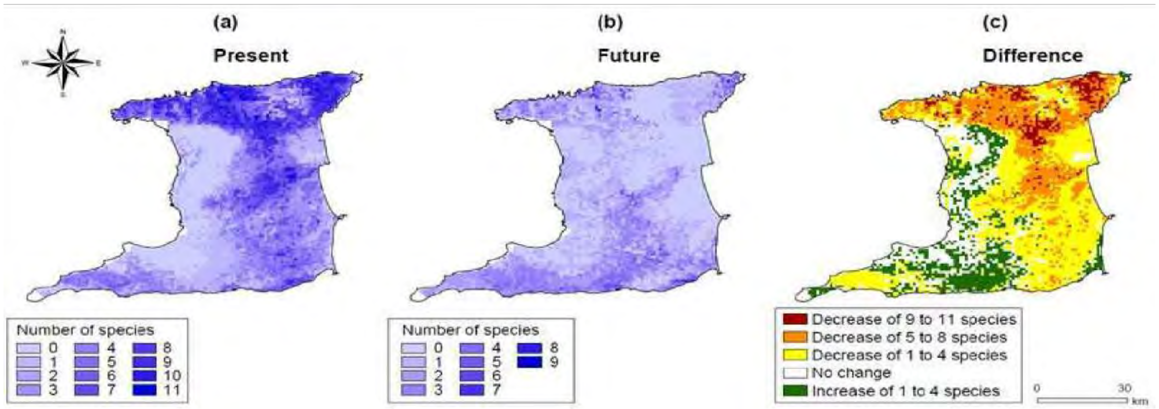


Figure 4.1: Preliminary modeling analyzes of 12 High Conservation Value tree species

4.2 Data Used in the Local Example: The Global to Local Climate Change Adaptation and Mitigation Scenarios (GoLo CarSce)

Data for this project was obtained on from:

i. The International Institute for Applied Systems Analysis (IIASA), Austria;
ii. PBL Netherlands Environmental Agency: Integrated Model to Assess the Globe Environment (IMAGE); and
iii. IPCC AR5 2013 climate model outputs and Coupled Model Intercomparison Project Phase 5 (CMIP5).

The Global Climate Models (GCMs) were then downscaled for the islands (from 150-200 km^2 resolution to about 10 km^2 resolution) using a super dell computer to create the first tier of model projections that included rainfall, temperature, humidity and soil temperature.

The data was calibrated using historical data from the Meteorological Services of Trinidad and Tobago (TTMS) and the Water Resources Agency (WRA). The process involved running the models backward to fit the historical data and then developing projections and comparing with the projections developed from the downscaled GCMs. Challenges in this process were encountered due to the poor archiving of historical data and limited data collection stations.

The second tier of the scenario development involved modelling the impact of various sectors - health, energy, tourism and agriculture - from the downscaled climate projections:

- Health impacts e.g. the spread of diseases
- Water availability
- Sea level rise and storm surge
- Forest and ecosystem services

The third tier of the scenario development comprised economic models. These models were developed using scientific data as well as socio-economic data, such as the IPCC's scenarios developed from Representative Concentration Pathways (RCPs) and Shared Socio-Economic Pathways (SSPs). Data was then filtered to a regional and local local level taking into account information on the Human Development Index (HDI) for the Caribbean country under consideration. According to the (UNDP, 2015), the HDI is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. The HDI was used in the socio-economic modelling as it was considered to be a better measure for assessing the development of a country, as opposed to the Gross Domestic Product (GDP), which measures economic growth only. Other sources of socio-economic data came from UNEP and FAO.

Chapter 5 - Conclusion and Recommendations

5.1 Conclusion

It can be concluded that Trinidad and Tobago, being among the most vulnerable countries to the impact of climate change, have recognized the need to assess the situation and take steps to lessen the negative consequences. This study highlights to importance of data in such approaches, as providing the foundation from which assessments can be made to inform appropriate actions. Presently, infrastructure exists to provide climate data, through both systematic observations and socio-economic analyses. Being the main focus of the study, the various categories of systematic observations were broken down into geospatial data, weather and climate data, sea level rise data and scenarios, data portals and scenario data. The systematic observations were found to be intertwined on the national, regional and global levels, where locally monitored data supplied regional and global databases and allowed for model projections; and in areas where there was no local coverage of data observation, global models allowed for extrapolation or downscaling to produce scenarios for local areas of interest.

Despite international guidelines and standards for systematically observed data, through the necessary information and regulatory bodies such as WMO and GCOS, many developing countries, including Trinidad and Tobago are still challenged by data gaps. The findings of this study showed the main issues to be insufficient data coverage, data access, data compatibility and data quality. A cross-cutting issue for Trinidad and Tobago, with regards to data coverage is the limited weather stations. Only two stations, one on each island of Trinidad and Tobago, were found to be sufficiently reliable to supply the international datasets. The other weather stations are not efficiently maintained because of lacking capacity in expertize and funding allocation. Also, there is still no official data protection and sharing policy within the country resulting in unwillingness to share data. While a vast amount of historical data exists, there has been no official strategy in data rescue and much of this data remains in paper archives where it is incompatible with current data processing systems and cannot be used. Apart from data incompatibility, issues in data quality were highlighted as a result of the low data resolution provided by general global models. Although the Caribbean region's main climate body, the CCCCC, has been a notably efficient coordinating centre, and good model example for other similar region, according to Parties in attendance of both the 2015 NAP Expo and the 2015 Bonn Climate Change Conference, their downscaling of data does not yet provide the quality needed to conduct detailed assessments on impacts. The centre is currently involved in a number of international partnerships, including with CORDEX, to better address this issue and other gaps in the climate change challenge.

Based on the socio-economic and sectoral reviews for the country, the notable areas projected to be affected by climate change include agriculture, health, human settlements, coastal zones, water resources, energy. The local adaptation project, GoLo CarSce attempts to inform stakeholders, including decision-makers, on the potential impacts for these sectors using systematically observed data to develop projected scenarios. Trinidad and Tobago's Second National Communications to the UNFCCC indicated that two specific areas where data gaps exists are biodiversity and marine and coastal resources.

GCOS has been working towards a coordinated solution of data standards and availability for all regions. However, Trinidad and Tobago faces a challenge in efficiently supplying local data to the international database, owing to the high requirements for temporal coverage, quality of data and standards of operation for individual weather stations.

5.2 Recommendations

In light of the gaps identified from the review of the climate data situation in Trinidad and Tobago, there are a number of recommendations that fit the needs of the country. The National Spatial Database Infrastructure (NSDI) presently underway for the country provides good model of elements needed to make not only the spatial data infrastructure more efficient, but also all other data infrastructure systems, including climate data. The recommendations for an improved climate data infrastructure, based on the NSDI and other findings from the review of the data situation are therefore as follows:

i. **Data rescue of historical or incomplete data and improved data coverage.** In Trinidad and Tobago a significant portion of data exists in a form that is incompatible with modern archiving and processing facilities. It is recommended that the importance of data rescue be stressed so that a strategy can be developed for its digitization or conversion to forms that can be useful, based on previous country models and established international standards. The quality control standards and specification of data from the international data bodies such as GCOS and WMO, and the NAP guidelines for data, under the UNFCCC is well described. Additionally, the network of observation stations should be increased to provide a more detailed coverage. Being a predominant issue within the findings of this study, high priority should be set. Both data rescue and improved coverage would need to attract funding and capacity building strategies.

ii. **The development, maintenance and support of data protection and data sharing policies.** In Trinidad and Tobago, as is the case in many other parts of the world, conflict arises from unauthorized or inappropriate data use and restricted data use. Data should be protected to allow for its use to be suited to its purpose and for the source of the data to be properly credited, as data is often difficult and costly to obtain. For this reason, data should also be made available to allow for progress in scientific studies on climate change and prevent wastage of time and resources on duplication of efforts. It is therefore recommended that non-profit organizations, individuals and student are allowed access free of charge, whereas corporate profit organizations are required to pay a cost-recovering fee for use of climate data produced by state agencies. In all cases, appropriate crediting of the data sources should be required.

iii. **Collaborative mechanisms and coordination among different agencies on a national, regional and international scale.** There should be improved linkages between subsidiary data collection bodies that supply the main reporting data bodies, for instance between WASA and TTMS. This ensures that the most updated information on data gaps and challenges are reported to the international systematic observation bodies and networks such as WMO, GCOS and GFCS, which then guide the UNFCCC's research and systematic observation agenda item during its consideration in the internationally mandated response to climate change. In addition, efficient collaboration and coordination prevents helps to avoid duplication of efforts. Additionally, local data supplied to international bodies allows for enriching of the global datasets and promotion of enhanced scientific assessments by the IPCC.

iv. **Enhancement and better overall coordination of capacity building for climate data specialists.** Similar to the NSDI plans, a research organization or unit within an existing research institution can be developed to prompt further research, innovation and training for stakeholders of climate data. The research unit would be responsible for training in new, emerging career fields and updating of skills in existing fields, as well as developing and maintaining a national climate database infrastructure, which would include a registry of data specialists, their fields and contact information. The climate database infrastructure can be developed in the form of an internet portal with open access and differential pricing schemes depending on users as outlined in ii. above.

v. **Ensuring that climate studies are guided by the best available science as indicated in the NAP, including considerations for traditional and indigenous knowledge in contributing to data needs.** In addition to considering points iii. and iv. above, the best available science should incorporate traditional and indigenous knowledge. The inclusion of traditional and indigenous data is important in filling data gaps that could only be accurately determined by the local people on the ground. The recommendation for 'ground truthing' in this instance involves outreach to persons within vulnerable communities, in particular, or communities where data gaps exist and undertaking educational outreach on climate change issues and capacity building in climate change data collection and population of a database. The database could take the form of an online portal, that could be integrated into a main database infrastructure as outlined in point iv. above. Incentives should be provided to prompt participation in the process and the infrastructure should be made available to the community members. Such infrastructure would include a computer lab with internet access, where trained community member can be responsible for uploading data as necessary. Additionally, the case studies produced by UNESCO on indigenous data could be reviewed for scenarios that may fit with the communities within Trinidad and Tobago. A project proposal has been made by the National Institute of Higher Education, Research, Science and Technology (NIHERST), a state agency under the Ministry of Science and Technology, Trinidad and Tobago, to their Ministry, for funding from September 2015 – September 2016, to begin a programme on the use of traditional and indigenous data to fill data gaps in climate change as outlined here.

vi. **Improving regional downscaling of global data models.** RD7 was heavily focused on the topic of regional downscaling, based on submission by Parties for the event. The dialogue aimed to address data and information gaps, including from the IPCC, as well as lessons learned and good practices for knowledge and research capacity building, with a focus on developing countries. As noted in the conclusions, the CCCCC has already begun strategies to improve the quality of downscaled data models through partnerships, including with CORDEX and via projects such as CARIWIG. Continued partnerships with such bodies are recommended to promote consistency in regional downscaling methods and approaches, as its benefits are well noted.

vii. **An integrated national approach to climate data management.** It is recommended that the issue of climate data be managed in a holistic manner to include scientific systematic observations, socio-economic and indigenous data, to inform climate change adaptation studies. This integration ought to take into account the sectoral and national needs of the country, such as the vulnerable sectors outlined in Appendix C. Studies like GoLo CarSce should be fully encouraged and endorsed. As they are already on the way to providing an efficient use of climate data by informing decision-makers on the adaptation and resilience measures that would be needed by the country in light of the most current scientific climate change data. Decision-makers should be made aware of the long-term economic value not only of adaptation measures to climate change, but also of climate data in providing the basis for these studies and priority should be placed on funding allocation to traditionally neglected areas such as weather monitoring stations. A monitoring and evaluation strategy should also be considered in any climate data plan proposed. And the integrated approach should go beyond the national context to the international regulatory elements such as the alignment of the NAP data guidelines with the guidelines set forth by GCOS and WMO, under the UNFCCC.

References:

Adaptation Learning Mechanism. (2009). *Trinidad and Tobago Country Profile*. Retrieved 2015, from Adaptation Learning Mechanism: http://www.adaptationlearning.net/trinidad-and-tobago/profile

Boodoo, C. e. (2009). The current status and development direction of the Trinidad and Tobago National Spatial Data Infrastructure (TTNSDI). *GSDI 11*. Rotterdam, The Netherlands: Global Spatial Data Infrastructure.

CCCCC. (2015). Retrieved March 24, 2015, from The Caribbean Community Climate Change Centre: http://www.caribbeanclimate.bz/

GCOS. (2015). *GCOS Workshop on Enhancing Observations to Support Preparedness and Adaptation in a Changing Climate - Learning from the IPCC 5th Assessment Report.* Bonn: World Meteorological Organization, 2015.

Government of the Republic of Trinidad and Tobago. (2013). *Second National Communication of the Republic of Trinidad and Tobago Under the United Nations Framework Convention on Climate Change.*

Government of the Republilc of Trinidad and Tobago. (2010). *Fourth National Report of Trinidad and Tobago to the Convention on Biological Diversity.* Montreal: Convention of Biological Diversity.

Inter-American Development Bank. (2014). *Understanding the Economics of Climate Adaptation in Trinidad and Tobago .*

IPCC. (2013). *WORKING GROUP I CONTRIBUTION TO THE IPCC FIFTH ASSESSMENT REPORT.* Geneva: IPCC.

IPCC. (n.d.). *Data Distribution Centre*. Retrieved May 2015, from http://www.ipcc-data.org/

LDC Expert Group. (2015, February 10-12). Needs for data and climate observations emerging in support of the NAPs and the work of the LEG. Bonn, Germany.

McSweeney, C.,New M. and Lizcano G. (2010). *UNDP Climate Change Country Profiles - Trinidad and Tobago.* Retrieved May 2015, from http://www.geog.ox.ac.uk/research/climate/projects/undp-cp/

Nurse, L. A. (2015). A Caribbean Perspective on Observed Impacts of Climate Change [PowerPoint slides]. *Structure Expert Dialogue 4.* Geneva: UNFCCC.

Pulwarty, R. (2015). *IPCC AR5 Working Group II: Observations to support adaptation planning and implementation [PowerPoint slides]*. Retrieved from http://unfccc.int/files/science/workstreams/systematic_observation/application/pdf/session4-1_pulwarty.pdf

Teichmann, C. (2015). Downscaling of CMIP6 for regional climate modeling: experiences from CORDEX [PowerPoint slides]. *Bonn Climate Change Conference - Research Dialogue 7.* Bonn: UNFCCC.

Trinidad and Tobago Meterological Service. (2015, May). Concept Note for a National Consultation on Climate Services & National Climate Outlook Forum for Trinidad and Tobago. Port of Spain, Trinidad and Tobago.

UNDP. (2015). *Human Development Index (HDI)*. Retrieved March 23, 2015, from United Nations Development Programme - Human Development Reports: http://hdr.undp.org/en/content/human-development-index-hdi

UNFCCC. (2007). VULNERABILITY AND ADAPTATION TO CLIMATE CHANGE IN SMALL ISLAND DEVELOPING STATES.

UNFCCC. (2014). *United Nations Framework Convention on Climate Change*. Retrieved February 2015, from http://unfccc.int/2860.php

UNFCCC. (2015). *Report on the structured expert dialogue on the 2013–2015 review.* Bonn.

Vladu, F. (2015, May 27). Systematic observations of the climate system under the UNFCCC: An overview. Bonn, Germany.

Appendices:

Appendix A: Regional Climate Projection Models by the CCCCC

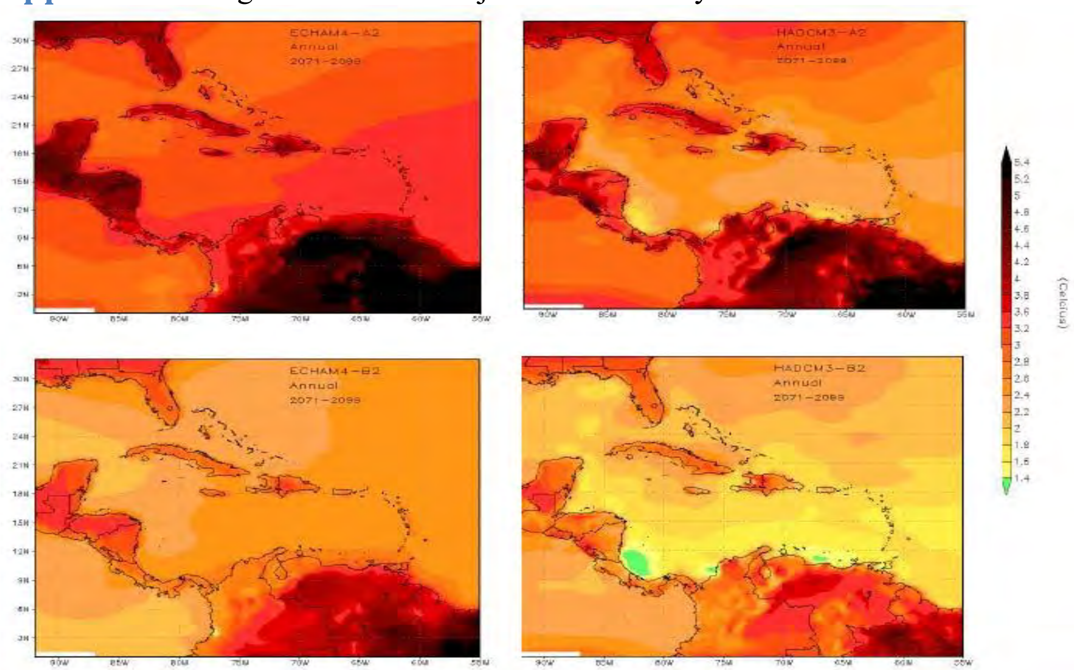


Figure 1: Temperature projections from 2071 – 2099 for the Caribbean region using ECHAAM4 and HadAM3P Models for A2[36] and B2[37] emission scenarios (*Source: Nurse, 2015*)

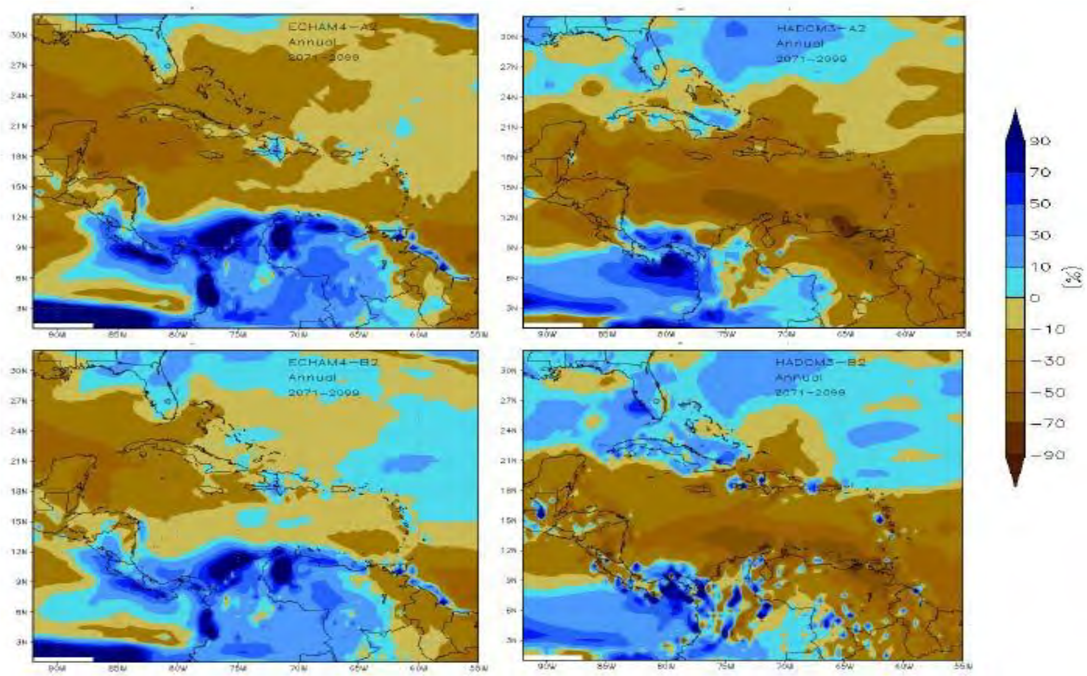
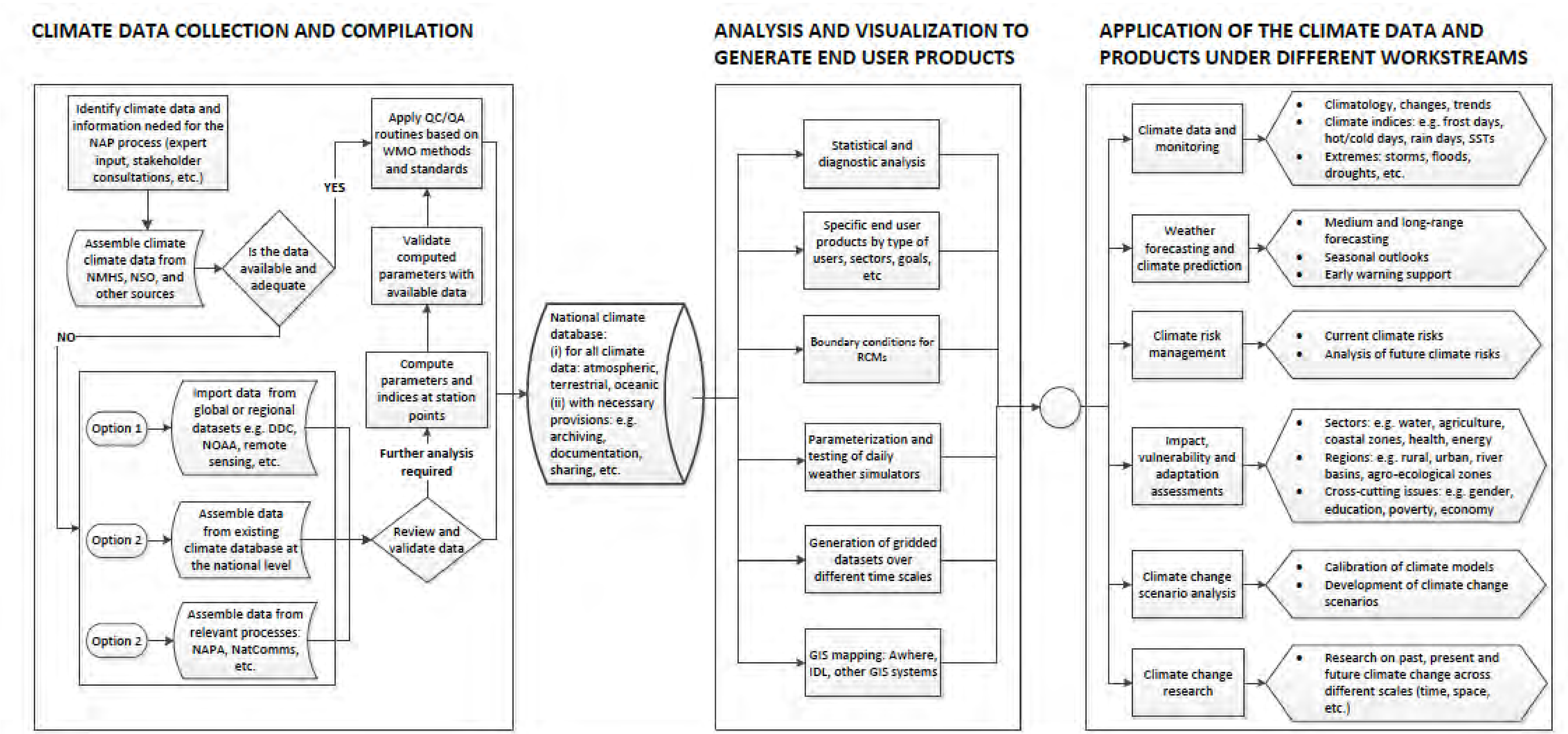


Figure 2: Precipitation projections from 2071 – 2099 for the Caribbean region using ECHAAM4 and HadAM3P Models for A2 and B2 emission scenarios *(Source: Nurse, 2015)*

---

[36] A2 scenario – Regionalization, emphasis on economic growth
[37] B2 scenario – Regionalization, emphasis on environmental sustainability

Appendix B: Key aspects of data and systematic observation (SO) under the NAP



Notes:

1. A list of essential climate variables is available at <https://www.wmo.int/pages/prog/gcos/index.php?name=EssentialClimateVariables>.
2. Acronyms: NMHS = national meteorological and hydrological services; NSO = national statistics offices; QC = quality control; QA = quality assurance; GIS = geographical information system; IDL = international data library; NOAA = National Oceanic and Atmospheric Association; GSOD = Global Summary of the Day.
3. Options 1, 2 and 3 under climate data collection and compilation are not exclusive to each other.
4. Information on the NAP process, the NAPs, guidelines and other additional information is available at <unfccc.int/nap>.

Figure 3: Flow diagram of guidelines for data and SO under the NAP
(Source: LDC Expert Group, 2015)

Appendix C: Potential effects of climate change by sector in Trinidad and Tobago

Table 1: Potential effects of climate change by sector in Trinidad and Tobago
(*Source: IDB: Understanding the Economics of Climate Adaptation in Trinidad and Tobago, Table 1*)

Sector	Impact
Agriculture	▪ Warmer weather from high temperature will cause soil aridity, lead to proliferation of pests and diseases, and put pressure on water resources for water for irrigation purposes. ▪ Sea level rise will cause inundation and soil desalination. ▪ The combined impact is low agricultural yields and decrease in food production.
Human Health	▪ Higher temperature will increase spread of vector diseases. ▪ Decrease in rainfall will affect potable water supply. ▪ Sea level rise will cause increases in water borne diseases.
Human settlements	▪ Increase in frequency and intensity of storm surge will cause more flooding and disrupt or destroy coastal settlements. ▪ Increase in frequency and intensity of storm surge and extreme rainfall will cause damages to infrastructure from flooding and erosion.
Coastal zones	▪ Sea level rise will lead to increased inundation, increased erosion, loss of wetlands, loss of ecosystems, and displacement of coastal communities. ▪ High temperature will result in loss of coral reefs and reduction in fish stock.
Water resources	▪ Increase in temperature will result in increased evapotranspiration and loss of available surface water. ▪ Decrease in precipitation will reduce groundwater and aquifer recharge. ▪ As an effect, available water resources will be reduced.
Energy sector	▪ Infrastructure, including field installations and offshore operations, are at risk of inundation from sea level rise, storm surges and erosion from extreme rainfall. ▪ Water shortages in the country may affect the needs of the industry in terms of energy generation. ▪ Infrastructure damages due to extreme weather events.

Appendix D: Sectoral data gaps identified during the GHG inventory in the 2013 Second National Communications of the Republic of Trinidad and Tobago under the UNFCCC

Table 2: Data gaps identified during the GHG inventory per sector

Period	Details
The Energy Sector	
1999 - 2006	• No imported lubricants • No feedstock (LPG, naphtha, natural gas, other fuels) • No fuel consumption for residential sector and agriculture/ forestry/ fishing
1990 - 2006	Fugitive emissions • Number of oil wells drilled • Number of oil wells tested • Number of producing and capable wells • The amount of gas stored • The amount of gas distributed • The amount of flared from production • The amount of gas vented from transmission • The amount of flaring and venting with respect to oil production

	• The amount of oil transported by tankers
1990 - 1997	Lubricants • International bunkers
The Waste Sector	
1990 - 2008	• Waste water
Industrial Processes Sector	
1990 - 2008	• PVC • Urea • Coffee roasting • Fish production
1995 - 2008	• Sugar production • Meat and poultry production • Animal feed
1998 - 2008	• Alcoholic beverage production (beer, wine, run, whiskey, etc.) • Margarine production
Agriculture Sector	
1990 - 2005	• Livestock subsector: - Dairy and beef cattle populations not available - Poultry data available only for broilers and for 1990, 1993 and 1996 - Pig data only for private farms and for 1990, 1993 and 1996 - No population data for buffalo, goats, sheep, horses, mules, asses, ducks, turkeys and geese - No local data on the relative distribution of animal wastes management systems • No data on acreages in rice production or on the proportion of rainfeds irrigated • The FAO database only provides distribution of irrigated vs rainfed for the year 1990 • No definitive data on the use of organic amendments in rice production • No data on residue/ crop ratio • No data on extent of residue burning except for sugarcane • Fertilizer N rates not known • Local data for fertilizer use not available after 1994 • No emission factor values for any of the categories
Land Use, Land Use Change and Forestry	
1990 - 2005	• Area of teak and pine forests only for 1990 – 1996 • Area of mixed hardwoods planted available only for 1995 • Roundwood production not available beyond 1996 • Fuel wood production only for 1994, 1996, 1997 and 1998 • Other wood sue data not available • No data available for forest area converted • No data on the fraction that is burnt on-site, off-site or left to decay • No data on agriculture land abandoned and allowed to regenerate naturally • No definitive information on the land use changes in relation to acreages and soil types • Except for an estimate from a local authority on area receiving lime, there is no data available on lime use

Appendix E: The IPCC's Four (4) Representative Concentration Pathways (RCPs)

The four RCPs represent radiative forcing values in the year 2100 relative to pre-industrial values and thereby aid in projecting the climate future based on the concentration of GHG emitted. Across all RCPs, global mean temperature is projected to rise by 0.3 to 4.8 °C by the late-21st century.

Table 3: AR5 projection of global warming temperature increase for the 4 RCPs
(Source: IPCC AR5 WGI: Summary for Policymakers; Table SPM-2)

	2046-2065	**2081-2100**
Scenario	**Mean and *likely* range (^{o}C)**	**Mean and *likely* range (^{o}C)**
RCP2.6	1.0 (0.4 to 1.6)	1.0 (0.3 to 1.7)
RCP4.5	1.4 (0.9 to 2.0)	1.8 (1.1 to 2.6)
RCP6.0	1.3 (0.8 to 1.8)	2.2 (1.4 to 3.1)
RCP8.5	2.0 (1.4 to 2.6)	3.7 (2.6 to 4.8)

Annex I: Ten messages from the SED on the 2013-2015 review

Message 1: A long-term global goal defined by a temperature limit serves its purpose well

Parties to the Convention agreed on an upper limit for global warming of 2 °C, and science has provided a wealth of information to support the use of that goal. Despite the irreversibility of global warming, cutting carbon dioxide (CO2) emissions now affects future warming within a few years. Removing CO_2 from the atmosphere results in cooling. Adding **other limits** to the long-term global goal, such as sea level rise or ocean acidification, **only reinforces the basic finding** emerging from the analysis of the temperature limit, namely **that we need to take urgent and strong action to reduce GHG emissions**. However, the limitations of working only with a temperature limit could be taken into account, for example, by aiming to limit global warming to **below 2 °C**.

Message 2: Imperatives of achieving the long-term global goal are explicitly articulated and at our disposal, and demonstrate the cumulative nature of the challenge and the need to act soon and decisively

Scenario analysis shows that limiting global warming to below 2 °C implies the following: a large reduction in global greenhouse gas emissions in the short to medium term, global carbon dioxide neutrality early in the second half of this century, and negative global greenhouse gas emissions towards the end of the twenty-first century. The longer we wait to bend the currently increasing curve of global emissions downward, the steeper we will have to bend it, even with negative emissions. **Limiting global warming to below 2 °C necessitates a radical transition** (deep decarbonization now and going forward), **not merely a fine tuning of current trends**.

Message 3: Assessing the adequacy of the long-term global goal implies risk assessments and value judgments not only at the global level, but also at the regional and local levels

The global climate determines regionally experienced risks. While global assessments of climate risks inform global policy choices and global risk management, they should be complemented by regional and local perspectives. A key element of these perspectives is the value judgment of when the scale (e.g. frequency and severity) of climate impacts results in a transition from ‘acceptable’ to ‘unacceptable’. This leads to a greater appreciation of the role played by all decision makers, including subnational authorities and cities.

Message 4: Climate change impacts are hitting home

Significant climate impacts are already occurring at the current level of global warming and additional magnitudes of warming will only increase the risk of severe, pervasive and irreversible impacts. Therefore, **the ‘guardrail’ concept, which implies a warming**

limit that guarantees full protection from dangerous anthropogenic interference, no longer works. This calls for a consideration of societally or otherwise acceptable risks of climate impacts.

Message 5: The 2 °C limit should be seen as a defence line

Limiting global warming to below 2 °C would significantly reduce the projected high and very high risks of climate impacts corresponding to 4 °C of warming, which is where we are headed under a 'business as usual' scenario. It would also allow a significantly greater potential for adaptation to reduce risks. However, many systems and people with limited adaptive capacity, notably the poor or otherwise disadvantaged, will still be at very high risk, and some risks, such as those from extreme weather events, will also remain high. Adaptation could reduce some risks (e.g. risks to food production could be reduced to 'medium') but the risks to crop yields and water availability are unevenly distributed. Moreover, the risks of global aggregated impacts and large-scale singular events will become moderate. **The 'guardrail' concept, in which up to 2 °C of warming is considered safe, is inadequate and would therefore be better seen as an upper limit, a defence line that needs to be stringently defended, while less warming would be preferable**.

Message 6: Limiting global warming to below 2 °C is still feasible and will bring about many co-benefits, but poses substantial technological, economic and institutional challenges

The costs are manageable, even without taking into account the co-benefits of mitigation, and various policy options could be deployed to manage the risks of the necessary mitigation action.

The feasibility of the long-term global goal could be assessed in an emerging, iterative, global risk management framework that has multiple feedbacks from different sources and takes into account planetary boundaries. To this end, periodic reviews would provide an opportunity to assess and reassess the overall progress towards reducing risks of climate impacts and progress of mitigation and adaptation action, thereby contributing to a science-based risk management of the pathways to a low-carbon and climate-resilient future.

Message 7: We know how to measure progress on mitigation but challenges still exist in measuring progress on adaptation

A generally accepted metric exists for aggregating and measuring overall progress on mitigation, but no single metric exists to quantify and aggregate the overall progress on adaptation. Similarly, a widely accepted metric to measure overall progress on reducing risks of climate impacts by adaptation would be required in the context of a global risk management framework.

Message 8: The world is not on track to achieve the long-term global goal, but successful mitigation policies are known and must be scaled up urgently

Greenhouse gas emission growth has accelerated, reaching a record high during the decade 2000–2010. The Cancun pledges are only consistent with the long-term global goal with pathways that require a much higher mitigation response later. Moreover, policies in place have had a limited impact on bending the emissions curve downward. However, successful mitigation policies have been identified and progress is being made on scaling them up, in particular in relation to putting a price on carbon and promoting otherwise low-carbon technologies, so that their share becomes dominant. **We need benchmarks for sound climate policy in the light of national circumstances.**

National information was not made available in a balanced manner for consideration by the structured expert dialogue, but such information could be considered in future reviews.

Message 9: We learned from various processes, in particular those under the Convention, about efforts to scale up provision of finance, technology and capacity-building for climate action

Many of the technologies required to achieve the long-term global goal are already available, but their deployment is not on track. Various barriers to their deployment and transfer have been identified. There is no widely accepted definition of climate finance, and uncertainties remain in the tracking of climate finance flows, in particular for adaptation finance and private finance, and to a lesser extent also for mitigation finance. Discussions are ongoing in various processes under the Convention regarding the resources required to address climate change under emission scenarios that limit the temperature increase to below 2 °C.

Institutions and processes launched under the Convention on technology and capacity-building have built a foundation for much greater effort, and progress has been achieved in the operationalization of the Green Climate Fund. The level of action now needs to be increased on all fronts.

Message 10: While science on the 1.5 °C warming limit is less robust, efforts should be made to push the defence line as low as possible

The science on the 1.5 °C warming limit is less robust than for the 2 °C warming limit or warming beyond this limit. Consequently, assessing the differences between the future impacts of climate risks for 1.5 °C and 2 °C of warming remains challenging. More scientific findings are likely to become available in the future, and considerations on strengthening the long-term global goal to 1.5 °C may therefore have to continue.

Nevertheless, limiting global warming to below 1.5 °C would come with several advantages in terms of coming closer to a safer ‘guardrail’. It would avoid or reduce risks, for example, to food production or unique and threatened systems such as coral reefs or many parts of the cryosphere, including the risk of sea level rise. On the other hand, this implies a more pronounced reliance on negative emissions with associated risks, including those from land-use change, as well as increases in mitigation costs in comparison with the 2 °C warming limit, and requires a larger temperature overshoot, which also carries certain risks.

However, while it is unclear whether the difference between 2 °C and 1.5 °C of warming is really only a matter of a gradual increase in risks or also includes some non-linear effects, as some evidence from the palaeo-record indicates, Parties may wish to take a precautionary route by aiming for limiting global warming as far below 2 °C as possible, reaffirming the notion of a defence line or even a buffer zone keeping warming well below 2 °C.