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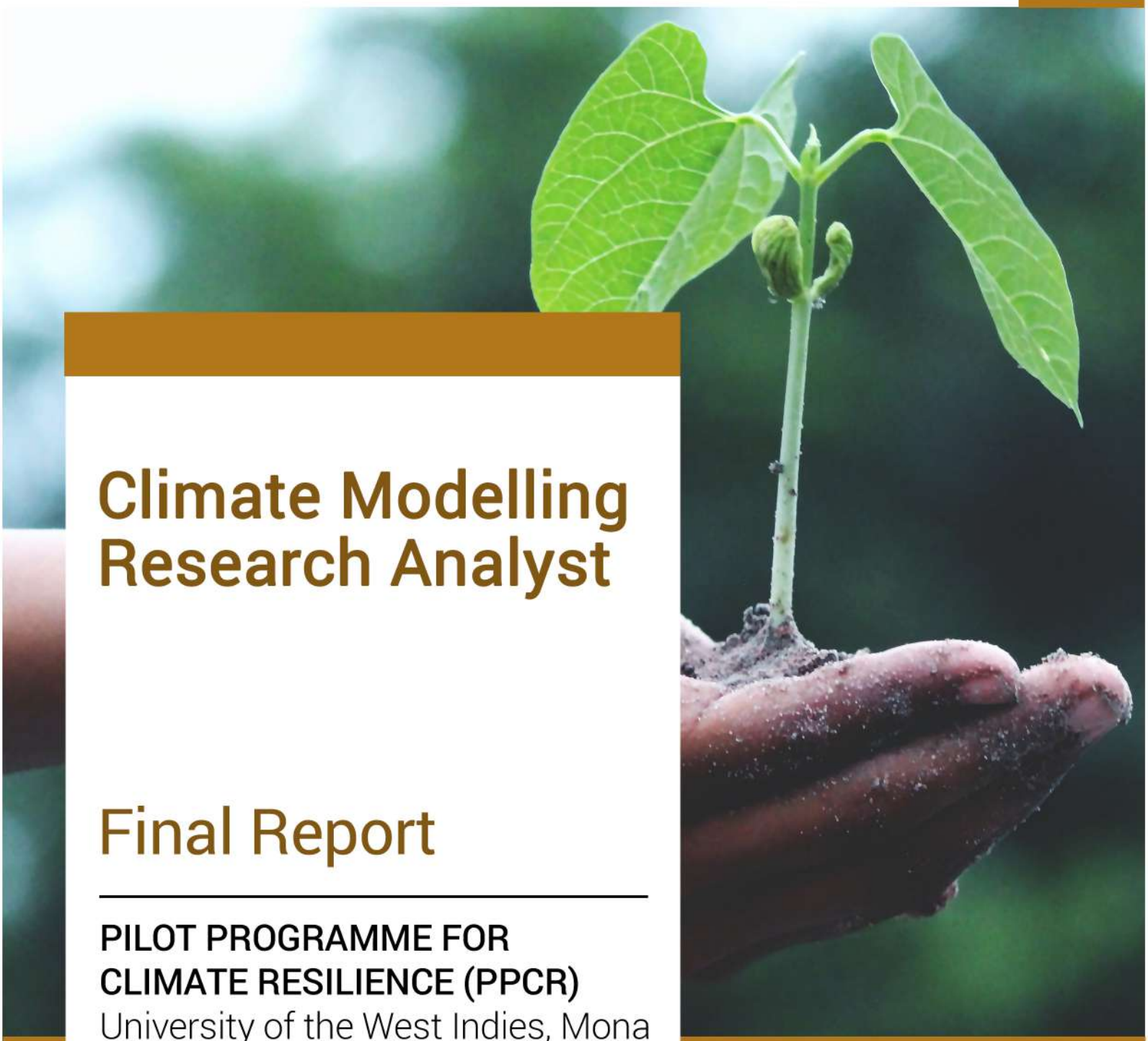

Climate Modelling Research Analyst

Final Report

PILOT PROGRAMME FOR CLIMATE RESILIENCE (PPCR)

University of the West Indies, Mona

Climate Modelling Research Analyst

Final Report

2019

RG-T2255 - Investment Plan for the Caribbean Regional Track of the Pilot Program for Climate Resilience

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Final report for Climate Modelling Research Analyst for 2019

Approved By

Tannecia Stephenson

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Name of Supervisor

Component 3 Focal Point

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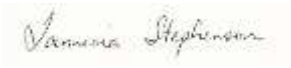
Position



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Signature of Supervisor

August 14, 2019

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Date

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Executive Summary

This report represents the Climate Modelling Research Analyst results and outputs for the third year that ended at July 3rd, 2019, and covers the following activities:

- Collaboration with consultant(s) assigned under Component 4 of the PPCR Regional Program.
- The transfer of new data to the High Performance Computing System.
- The analysis of key areas of climate including extremes using regional models centred over the Caribbean region.
- The generation of new climate change simulations using new regional climate models and scenarios.
- The presentation of key findings in technical, non-technical and peer-reviewed publications and documents.
- Knowledge and data sharing with regional stakeholders.

The activities outlined fall under either one of 3 key objectives of the consultancy:

1. Generation of new modelling outputs using the High-Performance Computing System
    a. Knowledge and data sharing across academic, impacts, adaptation, and vulnerability communities within the region.
2. Analysing four focal areas of climate:
    a. drought
    b. climate extremes, including the determination of 100-year precipitation events for select areas and heat stress,
    c. model uncertainties,
    d. model physics and setup.

Across the two key objectives listed above, varying degrees of success was achieved, as much effort was dedicated to the generation of new modelling output. Although new modelling output is still being generated, the consultant's successful completion of the knowledge and data sharing component in Objective 1 resulted in it having the greatest level of success.

List of Tables and Figures

Introduction

The primary focus of the second extension - starting July 4th, 2018 and ending July 3rd, 2019 - of the climate modelling consultancy was the continuation and completion of generating new downscaled future climate projections for the Caribbean in support of adaptation planning, decision making, and sector level modelling. This meant focus was on the completion of four (4) key but broad tasks/activities. These activities could be grouped into two larger objectives

1. Overseeing the generation of new modelling outputs using the High-Performance Computing System; or
2. Analysing four focal areas of climate.

The activities grouped under objective 1 were:

- Using the High-Performance Computing System – henceforth SPARKS, to generate new climate change simulations using new regional climate models and scenarios.
- Knowledge exchange and training of relevant stakeholders who use climate data to inform policy and or research.
- Provision of data for the development of Data sharing Platform for use by the impact and adaptation community.
    - Collaboration with consultant(s) assigned under Component 4 of the PPCR Regional Program

Activities listed under objective 2 were

- The analysis of key areas of climate including extremes using regional models centred over the Caribbean region.
    - The presentation of key findings in technical, non-technical and peer-reviewed publications and documents.
- Attendance and participation in climate related workshops and conferences

The following sections will detail the successes, challenges, and outcomes of each of the four (4) key activities conducted over the period.

Objective 1

The generation of new climate change experiments using SPARKS

The activity of generating new climate change experiments is a multifaceted one that involved:

1. The selection, configuration, installation and testing of the regional climate model
2. The selection of retrieval of the driving global climate data.
3. The parameterization of the model so that the model effectively simulates know climate features of the region
4. Configuring and conducting climate change experiments.

Action items 1 through 3 were completed in years 1 and 2 of this consultancy, so of sole priority was action item 4. Notwithstanding this, however in the next section we provide a brief description of the model used to generate new climate change experiments, the domain of over which the experiments were conducted as well as provide a summary of all new experiments completed and ongoing.

Regional Climate Model

The regional climate model selected for use for the generation of new climate change experiments centred on the Caribbean was the International Centre for Theoretical Physics – ICTP – Regional Community Model, RegCM, version 4.6.0 This version of the model was chosen because it allows for the selection of hydrostatic and non-hydrostatic cores, enabling downscaling beyond the horizontal resolution of 12km. Additionally, the model is freely available and has a large public repository of global climate forcing data including the current Intergovernmental Panel on Climate Change Representative Concentration Pathway (RCP) scenarios on which downscaling efforts will be Focused. Table 1 provides a list of all the RCP global forcing data acquired with a view to downscale to resolutions befitting the Caribbean.

Table 1 : Table showing all the Driving Boundary Data downloaded for use with RegCM. light shaded boxes indicate data downloaded prior to the year of reporting and dark shared boxes data downloaded during this years reporting period.

GCM	RCP2.6	RCP4.5	RCP8.5	Historical	Reanalysis
CanESM2					
CCSM4					
CNRM-CM5					
CSIRO-MK36					
EC-EARTH					
GFDL-ESM2M					
HADGEM2					
IPSL-CM5A-LR					
MIROC5					
MPI-ESM-MR					
MPI-ESM-LR					
NORESM1-M					
EIN15					
EIN75					
ERA5					
ERA40					
NNRP1					
NNRP2					

Although the parameterizations of the model; which involved the execution of several 1-month ERA40 experiments; yielded an optimal model time step for resolutions better than 30km of 30 seconds, several convective errors resulting in the premature termination of model experiments occurred. This resulted in a further increase in the anticipated time for the completion of model experiments which increased from factor of 3, to a factor exceeding 7 for some experiments.

Caribbean Domain

With the aim of making the results of downscaling activities available to the scientists across the globe, the CORDEX Domain with the spatial extent shown in *Figure 1* was chosen The domain in *Figure 1*, was used primarily to generate downscaled results with resolutions greater that 30 Km, but less than 15 Km. Above the 15 km horizontal resolution subsets of this domain were created and used.

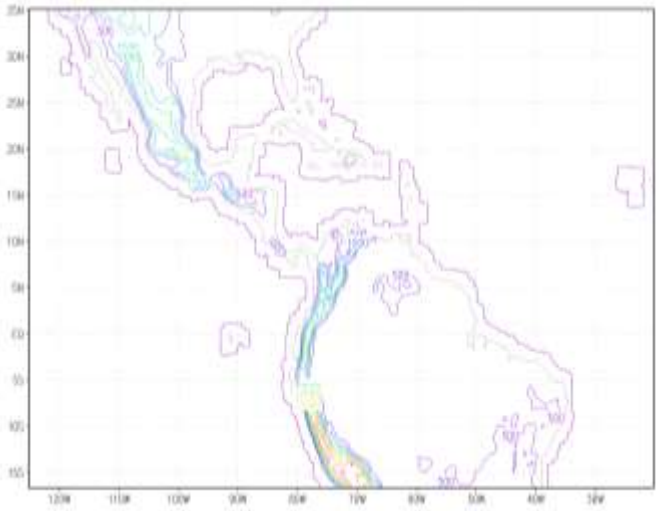

Figure 1 - Figure showing the Domain used for the generation of new climate change runs.

New Runs

In order to generate new climate change experiments using RegCM a few pre-processing steps are required. These involve the configuration and generation of model terrain, the driving sea surface temperature as well as the initial boundary conditions for the associated scenario and driving GCM. This process can take in excess of 20 – 30 days and must be entirely redone if any errors or failures are noted, this is further affected by power outages.

Of the driving boundary data noted in Table , the first model selected to be downscaled was the HADGEM GCM. This is in part owing to its performance in simulating key features associated with

Caribbean climate and it history of use in the Caribbean. See **Error! Reference source not found.** for a list of status of completion for the Climate Change experiment commenced thus far.

Table 2 : Table Showing the Status of New Climate Change Experiments Centred on the Caribbean. Statuses in red were achieved in the reporting year.

Experiment	Driving Data	Status	Resolution	Temporal Coverage
ERA40	Reanalysis	Completed	25KM	1958 – 2002
EIN15	Reanalysis	Completed	25KM	1979 – 2016
EIN75	Reanalysis	Completed	60KM	1979 – 2016
EIN75	Reanalysis	Completed	25KM	1979 – 2016
NNRP1	Reanalysis	Completed	25KM	1948 – 2002
NNRP2	Reanalysis	Completed	25KM	1979 – 2002
HADGEM2	RCP2.6	Completed	25KM	2019 – 2100
HADGEM2	RCP4.5	Completed	25KM	2019 – 2100
HADGEM2	Historical	Completed	25KM	1959 – 2004
HADGEM2	RCP8.5	Completed	25KM	2019 – 2100
HADGEM2	RCP2.6	Queued	10KM	2019 – 2100
HADGEM2	RCP4.5	Queued	10KM	2019 – 2100
HADGEM2	Historical	Ongoing	10KM	1959 – 2004
HADGEM2	RCP8.5	Queued	10KM	2019 – 2100
GFDL	RCP2.6	Queued	25KM	2019 – 2100
GFDL	RCP4.5	Queued	25KM	2019 – 2100
GFDL	RCP8.5	Queued	25KM	2019 – 2100
GFDL	Historical	Queued	25KM	1959 – 2004
MPI-ESM-MR	RCP2.6	Ongoing	25KM	2019 – 2100
MPI-ESM-MR	RCP4.5	Queued	25KM	2019 – 2100
MPI-ESM-MR	RCP8.5	Queued	25KM	2019 – 2100
MPI-ESM-MR	Historical	Ongoing	25KM	1959 – 2004
CSIRO-MK36	Historical	Queued	25KM	1960 – 2004
CSIRO-MK36	RCP4.5	Queued	25KM	2020 – 2100
CSIRO-MK36	RCP8.5	Queued	25KM	2020 – 2100
CanESM2	Historical	Queued	25KM	1960 – 2004
CanESM2	RCP4.5	Queued	25KM	2020 – 2100
CanESM2	RCP8.5	Queued	25KM	2020 – 2100

Successes of Objective 1

- All known available climate model data centred on the Caribbean were archived
- Additional driving GCM data has been identified and downloaded to expand the set of GCMs available to be downscaled.
- In addition to previous experiments a suite of new climate modelling scenarios were initiated and are underway on SPARKS
    - MPI-ESM-MR RCP 2.6 – 4 or 80 years complete at 20km
    - MPI-ESM-MR Historical – 8 of 35 years complete at 20km
    - HADGEM Historical – 5 or 45 years complete at 10km
    - Completion of EIN75 at 25 km
    - Completion of NNRP1 at 25 km
    - Other GCMs have been configured and queued at 20KM.
    - Experiments that have complete stage 1 (downscaled at 20KM) have now been queued and set up to run at 10KM (stage 2)

- All completed scenarios at the 20 KM horizontal resolution as well as data gleaned from other previous experiments across the region were prepared and shared for the preparation of a data sharing and dissemination platform.
    - A "soft launch" of the platform was shared and demonstrated for regional stakeholders, the feedback is currently being used to complete the platform for an official launch.
- Data was successfully shared with researchers in the Caribbean region and in South America. The data will be used toward the completion of ongoing PhD studies.
- Graduate students and lecturers from the Department of Physics were trained in the use of the SPARKS environment. This expanded the base of users as SPARKS now facilitates research disciplines such as Renewable Energy, Material Science, Forensics (Fire Research).

Challenges Faced in Objective 1

- As the University made strides to become its own electricity provider, major power outages as well as its resulting effects, re internet and associated components provided more than a month of delays. This issue although reduced at the end of June, were still being experienced and often resulting in weeklong outages. This would affect queued as well as ongoing experiments which would need to be restarted once power and the associated components were again available.
    - Augmenting this issue is the fact that failures of this nature do not allow for alerts to be sent so hours or days of scenario generation time will be lost before experiments can be re-initialized.

  Although an optimal time parameter was found through prior parameterization, CFL violation errors that resulted in the termination of ongoing experiments were still encountered. The extent of this issue was mitigated by the presence of a "watcher script" and an email server that provided electronic updates of a change in status and state of all experiments. To not increase the overall time complexity the decision was taken to leave the time parameter at a model time step of 20 seconds and adjust only when the unexpected and intermittent CFL error was experienced.

- Owning to the large volume of data being generated at stage 1, the decision was taken not to preserve seldom or rarely used files that are required to re-initialise downscaling efforts. This resulted in the liberation storage in excess of 100TB, but requires experiments be entirely re-run should any later issues be discovered.

Objective 2

The analysis of key areas of climate.

The analysis of key areas of climate using regional climate models centred on the Caribbean resulted in the preparation of technical, non-technical and peer-reviewed publications. These at the time of preparing this report were at different stages of readiness or publication.

The technical and non-technical publications prepared over the period are as follows:

1. Climate Studies Group Mona, in press The State of the Caribbean Climate 2017.
2. J Campbell, In progress: Imminent, distant or Unlikely: Evaluating Paris Accord thresholds for the Caribbean from a high-resolution regional climate model ensemble

The peer–reviewed publications prepared, submitted, published or in preparation over the period in question are:

1. In press: Regional Climates [in "State of the Climate in 2018"]. Bull. Amer. Meteor. Soc.,
2. (In progress): Alive at 1.5? Future Caribbean climate from a high-resolution regional climate model ensemble
3. (In progress): The effect of domain size on the detection of Tropical Cyclones in global and regional climate modelling data.

Participation in conferences and workshop.

Participation was had in several local and international conferences, meetings, and workshops. These ranged from Training in Crop Modelling to workshops examining synergies in the research areas of climate, sea level rise, climate modelling, climate impacts, hydrology and tropical cyclone identification between Bristol University and their counterparts at the University of the West Indies.

The consultant also led several training and information sharing exercises on the use of the high-performance computing cluster which were attended by University staff and students.

Successes of Objective 2

- The preparation, submittal or publication of seven technical, non-technical and peer-reviewed publications:

Submitted articles and reports

1. The State of the Caribbean Climate 2017.

Articles in preparation

1. Alive at 1.5? Future Caribbean climate from a high-resolution regional climate model ensemble
2. The effect of domain size on the detection of Tropical Cyclones in global and regional climate modelling data.
3. Imminent, distant or Unlikely: Evaluating Paris Accord thresholds for the Caribbean from a high-resolution regional climate model ensemble

Conferences, meetings, and workshops

1. Crop Modelling Simulation Workshop, held in the Department of Physics at the University of the West Indies, Mona Campus (UWI Mona), July 16 – 20, 2018.
2. Cyclone Risk in Small Island States Workshop, UWI Regional Headquarters, July 23 – 24, 2018.
3. Caribbean Climate Modellers Meeting, Department of Physics, UWI Mona, July 25, 2018.
4. Frontiers of Science, Chicheley Hall, London, UK, March 19- 22, 2019

Personnel Trained

1. Four graduate students and lecturers attached to the Faculty of Science and Technology, with disciplines ranging from Material Science, Renewable Energy, Fire Research and Computing.

Challenges Faced in Objective 2

- Time spent resolving issues noted in Objective 1 effectively delayed and hindered progress in Objective 2.
- Intermittent failure of new climate modelling experiments due to CFL violation errors as well as power outages precipitated a shift in focus and further delayed commencement and completion of consultant led peer-reviewed publications.