CARIWIG Case Study Report No 9

Flood risk and Urban development in Belize City, Belize

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Summary

- Belize has a total area of 8,867 square miles (22,700 square km) and as of 2010, a population of 322,453. Approximately 18% of the population lives in Belize City which is the country's main port, financial centre and tourism hub.
- The climate change projections analysed here indicate a substantial increase in temperature, particularly in June, July and August, and a decrease in rainfall during these months, especially nearer the end of the century.
- There may also be an increase in the intensity and variability of rainfall in the last months of the year. These changes may pose more problems for Belize City which is already prone to flooding even from a few hours of rainfall.

Aim and objectives

The purpose of this case study was to:

- Briefly explore the problems faced by Belize City especially in terms of flood risk and intense rainfall.
- Demonstrate the possible uses of the Weather Generator tool outputs by reviewing future projections of rainfall, temperature and extreme events for the City.
- Assess the implications of these projected changes for the Belize City area and populace and provide policy-relevant information.
- Suggest issues to be addressed in planning and policy making in relation to weather events that may impact the Belize City area and suggest areas for further research.

The main motivation for this study was to look at flood risk and urban development in Belize City. The City has experienced many issues in its past including frequent flooding, poor drainage and unplanned urban growth and development. It is very flat (basically at sea level) and this makes drainage of water very difficult - creating flooding situations which are compounded by the lack of proper drainage planning in the past.

Which tools were used? How and why?

Although the interest in Belize City was primarily in flood risk, the capacity for high-resolution hydrological modelling was unavailable. However, an analysis of past extreme weather events determined that rainfall provides some indication of flood risk, although a one-to-one, linear relationship was not discovered. The weather generator (WG) was chosen for this study because it provides daily time series at a point location in the City (Philip S. W. Goldson International Airport (PSWGIA) weather station) which provided sufficient data to run the WG. These time series could then be directly compared with observations and could, in effect, correct for some of the biases in the PRECIS regional climate model (RCM). Change factors from PRECIS were used to run the WG for the future. Two global climate models (GCMs), (aenwh from the UK Hadley Centre Met Office; echam5 from MPI, Germany) were used with PRECIS to take some account of climate model uncertainty. Plots of 100 WG runs each were produced for three different future scenario periods: 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-

2099). Rainfall thresholds of 50mm, 80mm, and 150mm were chosen based on an analysis of flooding events that have affected the City in recent years. Other extremes analysed included Warm nights (percentage of days when daily minimum temperature is above the present-day 90th percentile), Warm days (percentage of days when daily maximum temperature is above 90th percentile), and Maximum 5-day rainfall amount.

The findings

From interviews with local stakeholders, it was determined that timelines for future planning documents typically range from 1-20 years. Thus the focus was on WG outputs for the 2020s (not shown here) and 2050s (shown here), assuming that stakeholders would be more interested in these shorter-term results.

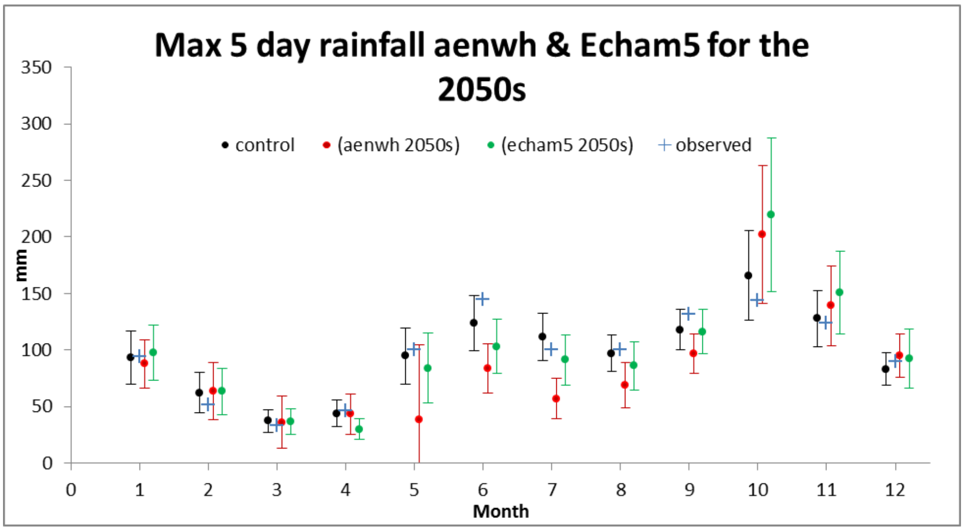
Comparison of Monthly Trends for Different Rainfall Variables from WG Projections for Both Models for the 2050s

Rainfall Variables	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Proportion of dry days	↑ ↑	↑ –	↑ –	– –	↑ ↑	↑ ↑	↑ ↑	↑ ↑	↑ ↑	↑ –	↑ –	– ↑
Mean wet-day rainfall	– –	– –	– –	– –	↓ –	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↑ ↑	– –	– –
Inter-annual variability	– –	– –	– –	– –	↑ –	↓ –	↓ –	– –	– –	↑ ↑	– –	– –
Days > 50mm	– ↑	↑ ↑	↑ –	– ↓	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ –	↑ ↑	↑ ↑	↑ ↑
Days > 80mm	– –	↑ –	↑ –	– –	↓ –	↓ ↓	↓ –	↓ ↓	↓ ↓	↑ ↑	↑ ↑	– –
Days > 150mm	– –	↑ –	↑ –	– –	– –	↓ ↓	– –	– –	– –	↑ ↑	↑ –	– –
Max 5 day rainfall	– –	– –	– –	– –	↓ ↓	↓ ↓	↓ ↓	↓ ↓	↓ –	↑ ↑	– ↑	– –

Legend: ↑(Increase), ↓(Decrease), – (no change in model); Orange (decrease in rainfall in both models) Blue (increase in rainfall in both models)

Left symbol = aenwh model; Right symbol = echam5 model

The table summarises rainfall WG outputs for the 2050s. The shaded cells show where runs forced by the two different GCMs agree on the direction of change - pink for a decrease in rainfall and blue for an increase. The projections show a higher proportion of dry days in June, July and August (accompanied by an increase in maximum temperature of about 2˚C in the 2050s). Mean wet-day rainfall reduces somewhat in JJA but inter-annual variability increases in October. Rainfall extremes show rather little change January to April, decrease from May to September, and then increase particularly in October and to a lesser extent November. The figure shown below provides a closer look at the Maximum 5-day rainfall total for the 2050s and again shows not much change in the early months of the year, a slight decrease from May to September, and an increase in October. For July, the mean of the 100 WG runs indicates an average decrease in maximum 5-day rainfall of 54mm for aenwh and 20mm for echam5 – from an observed value of 100mm. The difference in magnitude of projected changes from the two models indicates the importance of considering inter-model uncertainty. The length of the coloured lines indicates uncertainty due to natural variability.



For October, the increase in maximum 5-day rainfall is 40-50mm for the two models, from a present-day value of 143mm. Here, though, the range across the 100 WG runs is very large. This figure and the previous table suggest lower rainfall levels in JJA with more high intensity and variable rainfall events in October and November. The latter variability may be a reflection of and could be compounded by hurricanes or tropical storms that pass during the hurricane season which runs from June to November. Plots for warm days indicate that for approximately every 10 warm days experienced in the present day, there might be an expected increase of 50 to 90 days for JJA, and an increase of 20-50 days in other months. Combined with comparable increases in warm nights, this indicates a continual increase in temperature through the 2050s and beyond.

In the stakeholder survey carried out, respondents commented that high and frequent rainfall has caused many flooding situations in Belize City especially due to poor drainage and flat elevation in the city. Increased intensity of rainfall may threaten infrastructure such as poorly constructed roads and buildings. If there is an increase in the intensity in rainfall, daily rainfall more frequently exceeds thresholds such as 50/80/150 mm and maximum five-day totals increase, citizens will face greater risk of severe flooding situations which could also increase health risks especially in the poorer areas of the city due to poor solid waste management and lack of proper infrastructure.

Implications for policy and planning

The availability of these tools and outputs will allow stakeholders to explore the implications of projected changes in climate for infrastructure and society and aid in policy and planning for future development goals.

An increase in temperature and decrease in rainfall in JJA months may result in decreased water availability in the City with effects on infrastructure. Drainage channels may become blocked with garbage and increased dust and debris would reduce the natural flushing or cleaning effect when it does rain. This would result in increased flood risk. City officials may have more work to clear up debris and clear drains. Increased presence of garbage may ultimately present health risks and rodent infestations, all the while reducing the efficiency of drainage canals.

It is also important to consider non-climatic issues which may exacerbate vulnerability to droughts and floods. Thus there is a need to effectively plan for and control population growth and expansion of unplanned housing units within the City limits. In terms of the most recent city plan, stakeholders stated that the aims and vision of the Belize City Master Plan (BZCMP) may not necessarily translate into day to day management and development of the City and instead result in unplanned quick-fixes that further deteriorate the city's ability to cope with climate change and other environmental, social and economic pressures. Several of the Master Plan proposals provide only short-term relief such as proposals to dredge the Belize River mouth to aid with frequent flooding in the city. However, if there is a strong hurricane or tropical storm this could then turn into a serious problem for the immediate population up to two miles away due to 'spill over' effects.

Additionally, stakeholders recommended that future development plans for the city need additional technical studies in order to identify mechanisms to control the City's development. These studies should be accompanied by city-wide consultations on the findings, and should lead to more effective Land-Use, Governance and Finance Plans for the City. There is also great need to revise current Building Codes and to integrate climate change into the engineering and design of infrastructure.

Feedback on the tools

The plots produced by the climate experts from WG outputs were readily interpreted once considerable guidance was received from the experts. The background papers provided aided somewhat in the understanding of the WG outputs. It was particularly challenging for the case-study team when initially only the raw output data were provided and were not effectively explained to the non-experts. When figures such as that shown above were provided, understanding became easier. Interpreting and condensing the large volume of information was also challenging but with considerable time and effort, was achieved. The availability of the Threshold Detector aided in identifying the vulnerabilities of the city to varying heavy rainfall levels.

What more could be done?

This brief analysis of both observed and scenario data focused on daily rainfall (and the risk of fluvial flooding) and temperature for Belize City. However, there is a great need for a complete flood risk and urban development assessment to be done for Belize City which could be more relevant by utilising climatic information. The ongoing Flood Mitigation Infrastructure Project currently being implemented by the Ministry of Works & Transportation could provide the baseline information about road and drainage networks which could impact flood risk and urban development within the City. Various stakeholders identified the necessity for the development of detailed spatial mapping of flood risk areas in the city (e.g. tools encompassing hazard and vulnerability layers).

Other important considerations include sea level rise, the lack of rain gauges on atolls and cayes in the offshore areas, and the need to collect and study storm surge data as such events contribute to some flooding events in the city. There is also some relationship between upstream rainfall and flooding in the city, which needs to be better understood and modelled. It would also be helpful to use more climate models in order to better capture the modelling uncertainty, as well as to consider more emissions scenarios. The A1B scenario used here is a 'business-as-usual' scenario – mitigation scenarios could also be considered. The availability of this additional information and further dialogue with stakeholders would surely improve sustainable planning and policy development for many different organizations within the city.

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