paper 3

CLIMATE, DENGUE AND PREVENTION:
OBSERVATIONS FROM THE CARIBBEAN

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ABSTRACT: The occurrence of Dengue fever cases in the Caribbean has been increasing since about 1990. The outbreaks are linked to temperature but not to rainfall. There are intra and inter annual variations in the timing of outbreaks. The projected 2 degree C increase in temperature due to climate change implies further increases in Dengue cases. Each year, Dengue outbreaks occur four to six weeks after the initial peak in temperature. This fact has been used to develop an early warning indicator of the occurrence of an outbreak, based on a 'moving average temperature'. The indicator will be tested in a pilot project.

Keywords: climate, dengue, infectious diseases, Caribbean

1. Introduction

The rationale for *Climate, Dengue and Prevention: Observations from the Caribbean*, a project funded by *The Threat of Dengue Fever: Assessments of Impacts, and Adaptation to Climate Change in Human Health in the Caribbean (AIACC)*, is three-fold.

First, Dengue is a problem for the Caribbean. Dengue is a vector borne disease, transmitted by the *Aedes Aegypti* mosquito. The illness commonly begins in humans with a sudden rise in temperature accompanied by facial flush and other non-specific symptoms. The fever usually continues for 2 to 7 days and can be as high as 40 degrees Celsius, possibly with febrile convulsions and hemorrhagic phenomena. In moderate cases, all signs and symptoms abate after the fever subsides. In severe cases, condition may suddenly deteriorate after a few days of fever - the temperature drops, followed by signs of circulatory failure, and the patient may rapidly go into a critical state of shock (dengue shock syndrome) and die within 12 to 24 hours, or quickly recover following appropriate volume replacement therapy. There are four serious types of Dengue and all four are present in the Caribbean.

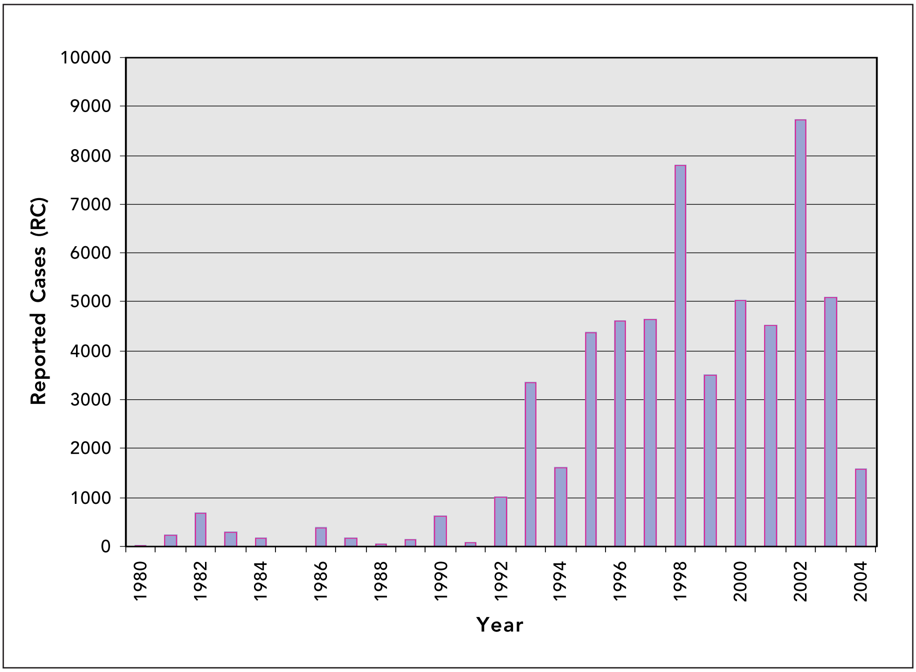

FIGURE 1

Reported Cases of Dengue in the Caribbean, 1980 to 2004

Figure 1 plots Dengue cases from 1980 to 2004 showing its steady rise, so there is no doubt that Dengue is a problem in the Caribbean.

Second, over the past twenty years, there has been a greater understanding of the Caribbean climate variability and change. More is understood about the climatology of the Caribbean and about the mechanisms that are driving this climatology. More is understood about the role of ENSO events in altering the climatology, particularly precipitation and temperature. Climate studies have identified climate change in the near past and are projecting future climate change.

Third, studies have shown that Dengue is a climate related problem for the Caribbean and that there is a climate signal in the Dengue epidemic. Some studies (Hales *et al.*, 1996; Gagnon *et al.*, 2001; Poveda *et al.*, 2000) have linked Dengue and ENSO events, though not necessarily for the Caribbean, but in French Guyana, Indonesia, Columbia, Surinam and various other regions around the world. Recent studies (Campione-Piccardo *et al.*, 2003; Depradine and Lovell, 2004; Wegbreit, 1997) have linked Dengue to specific climate variables, such as temperature and rainfall, in the Caribbean and elsewhere. The life cycle of the Dengue disease is sensitive to particular climate variables. Higher temperatures should lead to increased transmission rates due to a shorter intrinsic incubation period (Focks *et al.*, 1995; Koopman *et al.*, 1991).

The AIACC project includes five major components:

1. A Retrospective Study linking climate and Dengue in the Caribbean;
2. A Vulnerability Study identifying who is most likely to be affected;
3. Generation of Future Climate Scenarios to determine if the risk will increase
4. Assessing the Adaptability to Changes to determine if an increased threat can be survived; and
5. Designing an Early Warning Scheme to provide advanced notice of the threat.

This paper discusses preliminary observations from the retrospective study that links climate and Dengue in the Caribbean, the vulnerability study, and the status of designing an early warning scheme that makes use of climate information to address the threat of Dengue.

The climate data are from the Meteorological Services of the region. The Dengue data are from the Caribbean Epidemiological Center, CAREC. The study period is from 1980 to 2001 because, that was when the Dengue cases began to increase. The data reported on in this paper are largely from Jamaica and Trinidad because they were among the most complete data sets available.

2. Caribbean Climate

There are three main observations about climate in the Caribbean gained from this study. First, hot weather is followed by wet weather. The wet season runs from about April to November and peaks in September, October and November. Temperatures peak slightly earlier in June and July. There is a seasonality defined as becoming hot first and becoming very wet later on.

Second, ENSO events alter both hot and wet conditions. Several studies (Chen and Taylor, 2002; Enfield and Alfaro, 1999) suggest that the weather is warmer and drier towards the end of an El Niño year. The effect continues into the El Niño plus one year which is also warmer and wetter. There are also some ENSO signals in the periodicity of temperature and precipitation variability in the Caribbean.

Third, statistical downscaling of global circulation models to generate future scenarios of climate in the region shows agreement among models of a 2 degree Celsius rise in temperature projected for the region by the 2080s, though there is no consensus on rainfall changes.

3. Occurrence of Dengue

There is a seasonality to Dengue outbreaks being reported in four-week cycles. Onset of an outbreak occurs somewhere in the sixth or seventh four week cycle and peaks towards the end of the year. Figure 2 shows cases

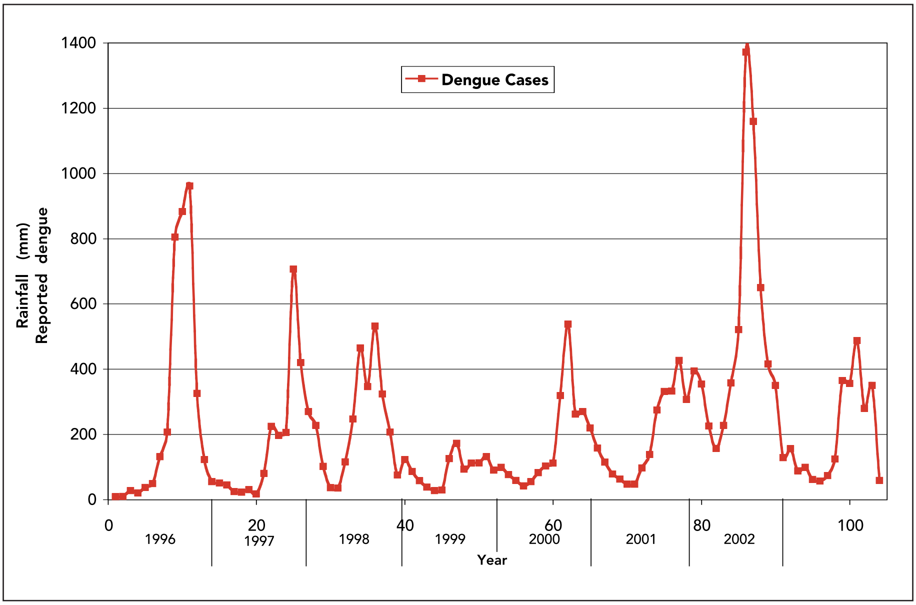

FIGURE 2

Reported Dengue Cases in Trinidad and Tobago for 4-week periods

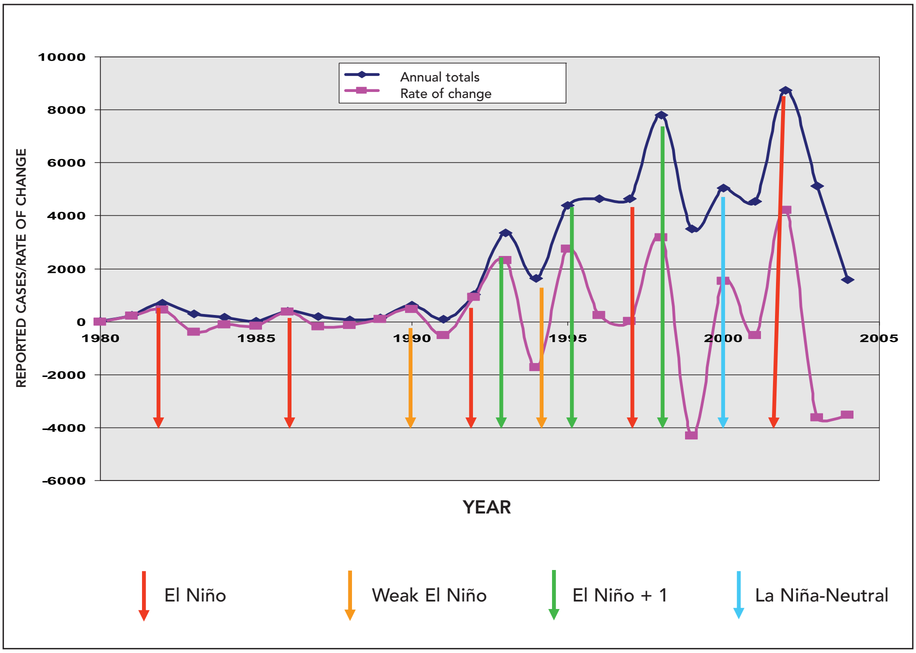

FIGURE 3

Reported Cases of Dengue in the Caribbean and Rate of Change, as well as links to ENSO

specifically for Trinidad and Tobago for the years 1996 to 2003, clearly identifying peaks towards the end of each year.

There is evidence of inter annual variability in the Dengue signal, as shown in Figure 3. This graph shows the Dengue cases in the Caribbean (diamonds) and the difference between one year and the next, or rate of change (squares). There are peaks and troughs that change from year to year, with an evident sharp increase in occurrences in the 1990s. There are also some evidence linking the peaks to El Niño years when there were alterations in temperature and precipitation. Some peaks are linked to El Niño plus one years, and some events link to La Niña years. There is some kind of periodicity in the Dengue signal and there is some kind of ENSO signal peaking in the Dengue occurrence in the Caribbean.

4. Climate/ Dengue Linkages

Having considered the observations of climate variations and of Dengue occurrences, it is appropriate to examine the relationship between the two. In the annual cycle of events, temperature increases are followed by precipitation increases followed by an increase in Dengue occurrences. In Figure 4, the diamonds are temperature for Trinidad and Tobago for 1997 and 1998; the squares are rainfall and the triangles are Dengue cases. Temperature increases rapidly and then rainfall increases; and towards the end of the years, there is an increase in reported cases of Dengue.

The strongest statistical association for outbreaks is with temperature rather than with rainfall, as shown in Table 1. Simple correlations between the reported cases of Dengue over the full time span do not indicate a significant correlation with rainfall; rather, they indicate a reasonable association with temperature, for the full time series, or for just the El Niño years.

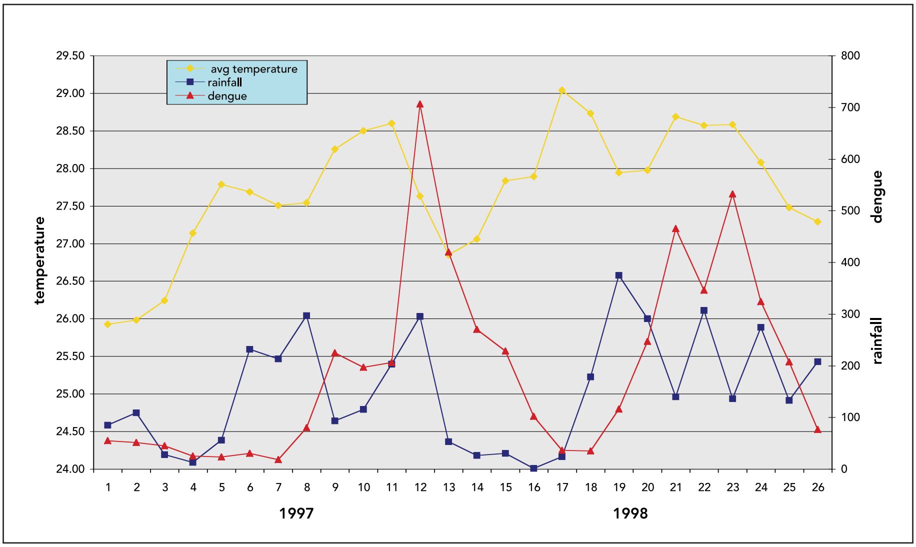

FIGURE 4

Average temperature, rainfall and Dengue cases for Trinidad and Tobago, 1997 and 1998

TABLE 1

Correlation results of annual Dengue cases with average annual TEMPERATURE and RAINFALL in the Caribbean

Country	Temperature	Rainfall
Trinidad and Tobago (1980 to 2001)	0.566	Not significant
Trinidad and Tobago (El Niño Years)	0.679	Not significant
Barbados (1980 to 2002)	0.479	Not significant
Barbados (El Niño Years)	0.585	Not significant
Jamaica (1980 to 2000)	0.428	Not significant

The onset of Dengue outbreaks occur four to six weeks after the initial peak in temperature. The range of values for statistical lags between the Dengue and temperature peaks is from three to seven weeks, but, for the majority of years it is four to six weeks (see Table 2).

TABLE 2

Onset of dengue and cross correlation between dengue and temperature in Trinidad and Tobago

Country	Year	Onset Period*	Statistical Lag*(r,p)
Trinidad and Tobago	1992	7th & 9th	6 (0.958, 0.001)
	1994	7th	4 to 5 (0.0.813, 0.014)
	1996	4th to 6th	5 (0.718,0.045)
	1997	7th & 10th	6 to 7 (0.823, 0.044)
	1998	4th to 5th	4 (Not significant)
	1999	6th	3 to 4(>0.77, <0.01)
	2000	4th & 8th	4 (0.72, 0.029)
	2001	6th	4 to 6(>0.8, <0.01)
	2002	4th	0 (0.568, 0.04)
	2003	4th to 5th	5 (0.649, 0.08)
Barbados	1995	7th to 8th	5 (0.841, 0.02)
	1996	7th to 8th (Not significant)	Not significant
	1997	5th to 9th	5 (0.932, 0.002)
	1998	4th to 6th	3 (0.708, 0.03)
	1999	6th to 9th	5 (0.858, 0.01)
Jamaica	1995	8th (onset could be earlier?)	4 (0.838, 0.01), 5
	1998	7th (onset could be earlier?)	3 (0.714, 0.03)

5. Vulnerability to Dengue Outbreaks

What is the vulnerability of the people of the Caribbean to further outbreaks of Dengue? A vulnerability study was carried out for three communities in western Jamaica that are prone to the outbreak of Dengue. Vulnerability indices were considered, such as immunity, knowledge of the symptoms, protective measures that are in place and sources of water. The three characteristics of the most vulnerable inhabitants were that they had little knowledge of Dengue transmission, the households were headed by a single female parent, and they had little or no access to piped water.

Water is widely stored in drums that have a high probability of producing large numbers of immature mosquitoes that lead to large numbers of mature mosquitoes. Water is stored in the drums whether the weather is wet or dry, which may explain why there is no link between Dengue and rainfall the source of infected mosquitoes does not depend on rainfall. Therefore, while climate may have a signal in the Dengue epidemic, the epidemiological indices and indices that relate to the vector population and vector density are also important. Indices such as the Breteau index (an index of vector population), the House index, the container index, or the pupae per person index, and epidemiological parameters must be measured at the same time as the climate parameters. Figure 5 shows the Breteau Index for the past 20 years for Trinidad and Tobago. It increased rapidly towards the end of the nineties, as did the number of Dengue cases.

6. Early Warning Systems

With regard to future changes, temperature has been shown to be an important variable in governing Dengue outbreaks. In terms of climate change, there is also a high certainty that the temperature will increase about 2 degrees Celsius in the future. The Dengue/temperature linkage suggests the possibility of using temperature information in an early warning system for Dengue outbreaks.

There are choices to make with respect to what temperature index to use in an early warning system. Peak temperatures are an obvious choice, but, it is too difficult to determine the actual peak during the course of the year. A temperature threshold and the rate of temperature rise were also examined. In the end, a moving average temperature was chosen.

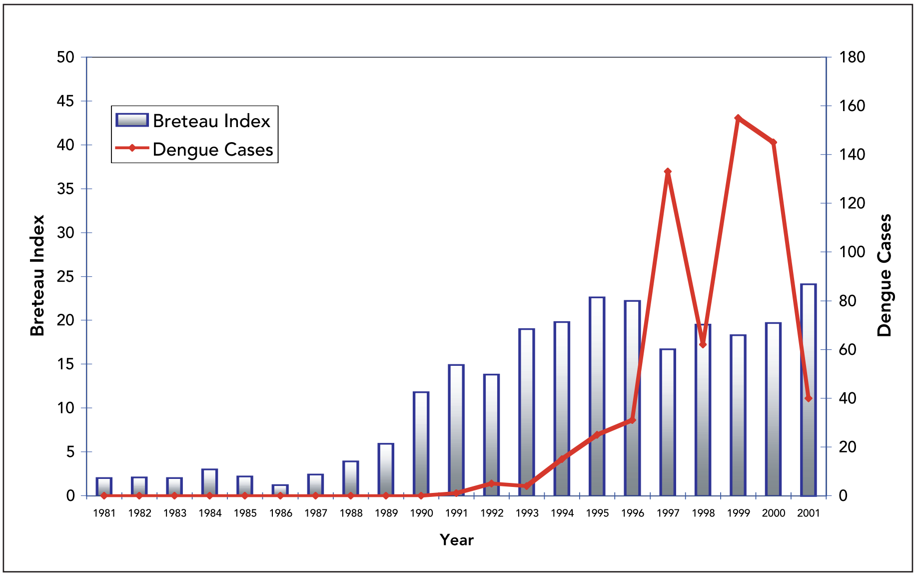

FIGURE 5

Dengue prevalence and *Aedes aegypti* Breteau indices in Trinidad and Tobago (1981-2001)

The moving average temperature (MAT) is defined as the average temperature up to any given time during the year. Since Dengue cases are reported in four week periods, after the first 4 week period, the moving average temperature is the average temperature of that 4 week period. After the second 4 week period, the moving average temperature is for the first 8 weeks, then 12 weeks, etc.

The moving average temperature has been applied in three ways. For each country, the MAT is calculated up until the onset of a Dengue outbreak called the 'onset MAT'. Onset is the point when the Dengue cases begin to rise, sometime in the middle of the year. The onset MAT is determined for each country for each year that there is a Dengue outbreak. An average onset MAT is calculated for each country. The average value is taken as the reference value. In subsequent years, for each country, the MAT values are tracked as they approach the reference value. For example, Table 3 shows the onset

MAT for Trinidad and Tobago for each year. The average onset MAT or reference value is 27.3 degrees Celsius. This is shown in Figure 6. The MAT values for each of four years are also plotted along with the corresponding reported Dengue cases. Once the MAT for a given year crosses the reference value, within about two 4 week periods, there is an onset of Dengue. If the MAT approaches the average onset value very slowly for a given year, then the onset of Dengue is delayed. This is not the case just for Trinidad and Tobago, but in Jamaica and Barbados. This kind of temperature threshold may hold some possibilities for using climate information in an early warning of the outbreak of Dengue.

TABLE 3

Moving Average Temperature (MAT) In Trinidad and Tobago

Year	Early Peak Temperature in °C	Temperature at Onset in °C	Lapse Time Between Early Peak and Onset	Onset MAT in °C
1992	28.3	27.0	2-4week periods	27.0
1994	28.4	27.8	2-4week periods	27.3
1996	27.8	27.8	< 4 weeks	27.2
1997	27.8	27.5	2-4week periods	27.1
1998	29.0	28.7	≤ 4 weeks	28.1
1999	28.5	28.5	< 4 weeks	27.5
2000	28.0	27.2	< 4 weeks	27.1
2001	28.8	28.1	1-4week periods	27.4
2002	28.0	27.7	< 4 weeks	27.0
2003	29.0	28.9	< 4 weeks	27.8

An early warning system must be applicable to present conditions, so that it can serve as a learning experience for future climate conditions. An early warning system must include climate surveillance, such as the MAT index and epidemiological surveillance (The Breteau Index or the pupae per person indexes are good examples of the vector abundance within the region). Knowledge of the presence of Dengue, below epidemic levels, will indicate the susceptibility of the country. In addition, the early warning system must

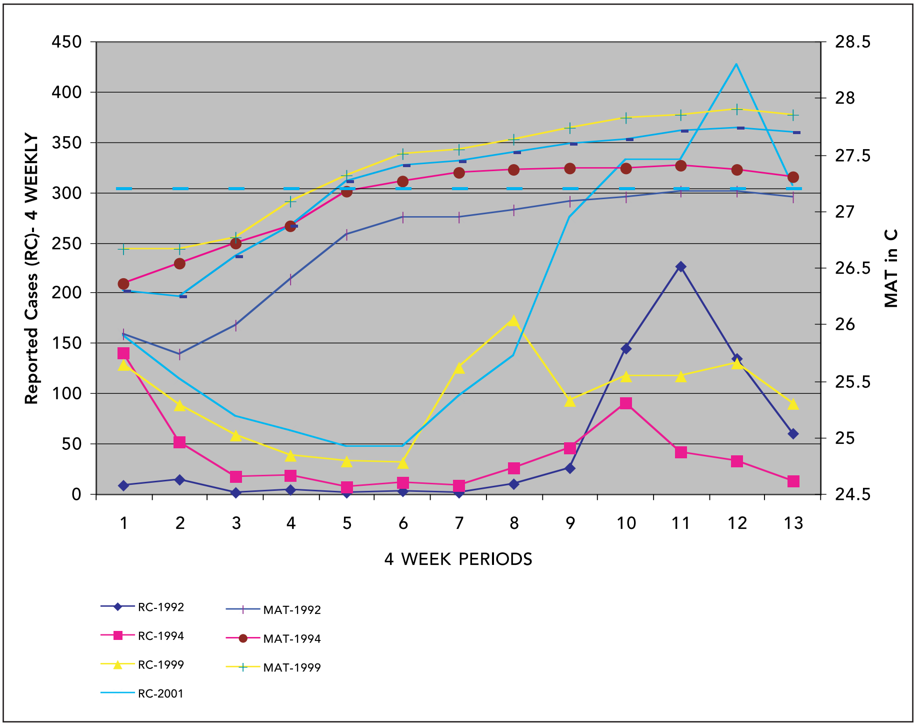

FIGURE 6

Reported Cases of Dengue, Moving Average Temperature (MAT) vs. 4-week periods in Trinidad and Tobago (1992, 1994, 1999 and 2001)

have response strategies that are: appropriate for the Caribbean region so that they can be implemented within the economic means of the region; and graded according to the level of severity indicated by the early warning system. That is, is there a strong possibility or a weak possibility of an outbreak? In addition, there must be ongoing disease prevention and risk analysis and vulnerability assessment.

It may be possible to produce a disease 'watch' or warning for each country, as is done for hurricanes in the region. However, this requires an appropriate response strategy, depending on whether it is a watch or a warning. The early warning system would be subjected to ongoing evaluation and feedback. An overall system can be summarized in Figure 7. The surveillance agents would

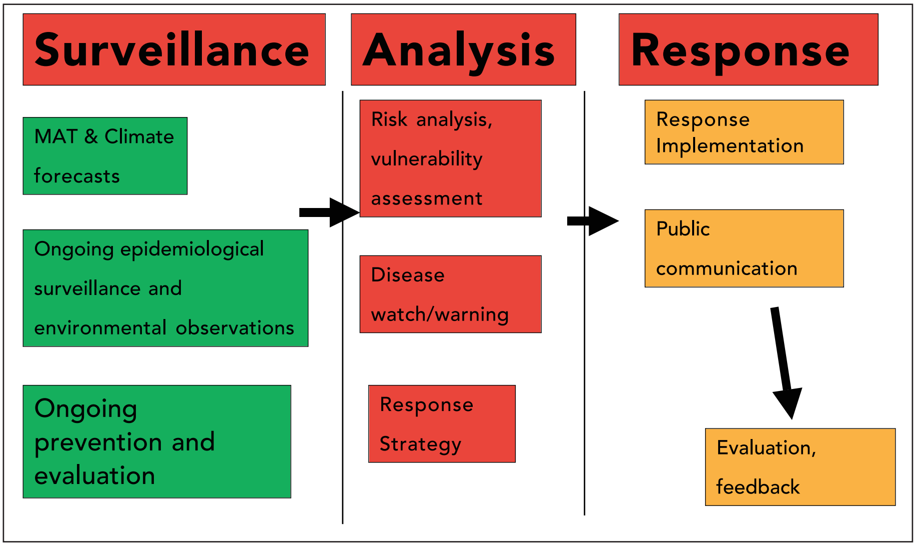

FIGURE 7

An Early Warning System for Dengue in the Caribbean

be the Meteorological Services, the Climate Research Institute and the Ministries of Health. The response agencies would primarily be the Ministries of Health and Meteorological Services.

The advantages of an early warning system would be to decrease the uncertainty about the onset of a Dengue epidemic. The system would be cost effective by helping to pinpoint when to increase surveillance of the epidemiological index. Its value can be enhanced by adding climate forecasts - using the output of models - to predict future Dengue outbreaks.

7. Conclusions

Dengue cases are increasing in the Caribbean. There is a climate signal in the seasonality and variability of the Dengue cases and while rainfall is important, there is a much stronger association with temperature. Temperature does not explain all of the Dengue increases. There is a projected 2 degrees Celsius rise in temperature due to climate change which implies an increased risk of Dengue outbreaks in the Caribbean. A temperature index has been developed as an early warning system that also incorporates surveillance of epidemiological parameters. Plans are being made to implement an early warning system of Dengue in the Caribbean based on climate variables in a pilot project.

Note: much of the results presented were expanded on in a later monograph listed below:

Chen AA, Chadee DD, Rawlins SC (eds.) 2007: Climate Change Impact on Dengue: The Caribbean Experience. Climate Studies Group, Mona, Kingston, Jamaica,104 pp.

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