DENGUE EPIDEMICS IN MIDDLE-SOUTH OF BRAZIL: CLIMATE CONTRAINTS (?) AND SOME SOCIAL ASPECTS

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Abstract. Dengue is currently one of the most serious worldwide public health problems. It is a disease of the tropical world, in which most of Latin America is located and where the environment and climate provide ideal conditions for the *Aedes* mosquito (*aegypti* and *albopictus*) to thrive. In addition the socio-cultural environment (urbanization and lifestyle) and an ineffectiveness of public health policies, result in severe epidemics of the disease. This research aims to analyze incidences of dengue fever in three different cities in Brazil: Campo Grande/Mato Grosso do Sul, Maringa/Parana and Ribeirao Preto/São Paulo and its statistical relationship to climate by correlating different climate variables to dengue incidence. Daily temperature analysis also shows significant correlation (R=0.70 and P>0.99) with disease incidence subject to a 7 days lag. In addition to climate and environmental factors, the mobility of population through by imported cases, has also been investigated. The results show the complexity of disease, in a strict relation between the environment (weather) and the mobility of the population, the circulation of different serotypes, the disposal of solid waste, debris and abandoned swimming pools, consequence ofthe indifference of the population to situations of risk and vulnerability to the disease. An important point to highlight is that, even in different cities, the epidemics followed a similar pattern, emphasizing the importance of climate variables (should also add the hypothesis of travel, serotype). Our study uncovered important relationships between dengue epidemics and climate, although more detailed studies on both serotype and transmission in cities are necessary to further understand the factors behind disease transmission. Our results could assist local health agencies on implementing appropriate early warning systems monitoring and preventive control actions by monitoring temperature conditions prior to the epidemics.
Key words: Dengue, climate, society, Centro-south, Brazil

EPIDEMIA DE DENGUE NO CENTRO-SUL DO BRASIL: CONDICIONANTES CLIMÁTICOS E ALGUNS ASPECTOS SOCIAIS

Resumo. A dengue é atualmente um dos mais graves problemas de saúde pública em todo o mundo. É uma doença do mundo tropical, no qual a maioria da América Latina está localizada e onde o ambiente e o clima proporcionam condições ideais para o mosquito *Aedes (aegypti e albopictus*) para prosperar. Além disso, o ambiente sócio-cultural (urbanização e estilo de vida) e a ineficácia das políticas públicas de saúde, resultam em graves epidemias da doença. Esta pesquisa tem como analise a incidência de dengue em três diferentes cidades do Brasil: Campo Grande / MS, Maringá / PR e Ribeirão Preto / SP e sua relação estatística com o clima, correlacionando variáveis climáticas diferentesde incidência da doença. A análise da temperatura diária também mostra correlação significativa (R = 0,70 e P> 0,99) com os registros da doença e um atraso 7 dias. Além do clima e factores ambientais, a mobilidade da população em relação aos casos importados também foi investigada. Os resultados mostram a complexidade da doença, em uma relação estreita entre o ambiente (clima) e a mobilidade da população, a circulação de differente sorotipos, a eliminação de resíduos sólidos, entulho e piscinas abandonadas, o que coloca a própria população em situações de risco e vulnerabilidade à doença. Um ponto importante a destacar é que, mesmo em cidades diferentes, a epidemia seguiu um padrão semelhante, enfatizando a importância das variáveis climáticas. Este estudo mostra importantes relações entre as epidemias de dengue e clima, embora estudos mais detalhados sobre ambos sorotipo e transmissão nas cidades são necessários para melhor entender os fatores por trás da transmissão da doença. Nossos resultados podem ajudar as agências de saúde locais na implementação adequada de alerta precoce a partir de sistemas de monitoramento e ações preventivas de controle de condições de ambientais.
Palavras-chave: Dengue, clima, sociedade, Centro-sul, Brasil

Introduction

Dengue is the most important arbovirus affecting humans and currently constitutes a serious public health problem worldwide. Globally, 2.5 billion people live in areas where dengue viruses can be transmitted. According to the World Health Organization (WHO), the current global scenario features hyper-endemic levels in many urban centers located in the tropics (WHO, 2011).

The *Aedes aegypti* and *Aedes albopictus* (L.) (Diptera: *Culicidae)* are the two vectors of dengue's fever. The dengue's virus belongs to the genus Flavivirus (*Flaviviridae* family) and its infection is caused by four serotypes that produce serotype-specific immunity. In its most severe clinical forms, it can manifest as dengue fever, hemorrhagic fever and dengue shock syndrome (Ministry of Health, 2005).

Especially in tropical countries, it can be seen that the conditions of the physical and natural environment (especially climate) associated with the social-cultural environment (urbanization) and ineffectiveness of public health policies, promote the development and proliferation of the mosquito (Mendonça, 2007) resulting in severe epidemics. Thus, in order to understand the issues of dispersion and transmission of dengue, it is necessary to address not only the behavior of infected individuals, but the correlation of all geographic and climatic features present in the urban environment.

Aedes Aegypti is the main vector of Dengue in Brazil according to the Brazilian Ministry of Health and it is normally found in urban areas, where as *Aedes albopictus* is found in rural areas.

According to Johansson *et al.* (2009), temperature and precipitation can influence dengue incidence. Abundance of *Aedes aegypti*, the predominant vector, is partly regulated by precipitation, which provides breeding sites and stimulates egg hatching.

Temperature influences the ability of both *aegypti* and *albopictus* to survive and determines their development and reproductive rates. Increased temperatures increase the frequency of feeding, decrease the time it takes for mosquitoes to become infectious and infecting another host within their lifespan (Johansson *et al.*, 2009).

The causes and consequences of the urbanization process, integrated with climatic variations, are gaining increasing importance in the study of disease transmission and control.

The increase in human settlements in cities has created scenarios conducive to the spread of the disease vector, because many cities do not offer appropriate garbage collection resulting in construction debris and tires accumulating in properties. Abandoned houses or poorly maintained swimming pools further accentuate the problem.

Higher rates of urban population increase the flow and mobility between cities and metropolitan regions, becoming another important factor in the spread of disease through the imported cases.

There is a close overlap between urbanization and changes in the local climate known as "heat island" effect. These effects are detectable on a global scale; however, a more comprehensive understanding of disease transmission also demands better knowledge of the regional and local conditions of their geographical setting, as well as the public policies and actions that have been established by society for its control.

According to Prinn (1999), the interaction between natural and social aspects of human development has gained special attention from the scientific community, resulting in the development of several models to integrate them. However, the advancement of these models for the purpose of this research requires the consideration of several key questions:

• How can the dynamic interactions between nature and society be most effectively incorporated into the latest models and conceptualizations that integrate the natural environment, human development and the dynamics of disease?
• Can "limits" be set for environmental / climatic systems beyond which society and nature can incur a significant risk of geographical spread of the disease?

We focus on three cities in Brazil where high rates of the disease and history of serious epidemics have been reported, to investigate the relationship between climate and dengue cases and understand how the temperature influence the proliferation of the vector. They are located in three states in the South-Central region of Brazil (Mato Grosso do Sul, Parana and Sao Paulo). These cities are also key transportation hubs experiencing a large flow of people and goods, thus allowing us to also study the importance of socioeconomic factors with respect to disease transmission.

1.Data

The dengue data used in this study are provided by two different sources, both federal (SINAN - Ministry of Health), state and municipal departments (http://dtr2004.saude.gov.br/sinanweb/index.php).

Monthly data of the serotype, imported cases, hemorrhagic fever and dengue deaths were acquired for Campo Grande, Ribeirao Preto and Maringa from January 2000 to July 2011. Daily data were obtained only for the Maringa's epidemic of 2006-2007, which allowed a more detailed analysis of that event.

Much of the meteorological data used for the purposes of this study were obtained through the International Research Institute for Climate and Society (IRI) Data Library system (http://iridl.ldeo.columbia.edu/index.html), which contains a wealth of information from satellites and weather stations throughout the world.

Land surface temperature (LST) data were obtained from the Moderate Resolution Imaging Spectro radiometer (MODIS) sensor, on board of Terra satellite at 1 km spatial resolution. The MODIS LST is derived from two thermal infrared band channels, *i.e.* 31 (10.78–11.28 μm) and 32 (11.77–12.27 μm) using the split-window algorithm (Wan *et al.,* 2002), which corrects for atmospheric effects and emissivity using a look-up table based on global land surface emissivity in the thermal infrared (Snyder *et al.*, 1998).

MODIS LST night time 8-day composite products have been shown to be in good agreement with minimum air temperature observations for twenty-eight stations in Africa (Vancutsem *et al.* 2010). MODIS nighttime Land Surface Temperatures from TERRA were used in this analysis as an estimation of minimum air temperature because the overpass of TERRA coincides with the time of minimum air temperature over Latin America. MODIS LST day time 8-day composite products were also combined with night time images to derive an 8-day composite mean temperature.

In addition, meteorological data from in-situ stations were also acquired from the INMET – National Institute of Meteorology (http://www.inmet.gov.br/sonabra/maps/automaticas.php) and IAC – Agronomic Institute of Campinas (http://www.ciiagro.sp.gov.br/ciiagroonline), to increase the reliability and accuracy of satellite information.

2. Methods

Monthly and seasonal timescales of dengue epidemics in relation to climate (temperature) was first analyzed by comparing time series of absolute values and anomalies between dengue and climate factors.

The value that defines epidemics is 100 cases and above per 100 000 inhabitants, parameter accepted by the Brazilian Ministry of Health and Pan American Health Organization (OPAS, 2007).

We also conducted this study based on Rhythmic Analysis (Monteiro, 2001), which uses the analysis of daily weather data elements such as temperature.

According to Monteiro (2001), the technique of rhythmic analysis of the climate is capable of representing, due to its fine temporal scale (daily), the interaction of the elements and factors within a regional geographic reality, aiding in the understanding of various social and environmental problems, such as dengue.

However, we used here a tailored approach to the study of rhythm climate in which we considered only the temperature and rain in the daily scale, associated with the data of dengue notifications, allowing a sense of the dynamics of the local climate and the epidemic.

Due to the difficulty in acquiring daily data of dengue, statistical analysis was performed only for Maringa during the epidemic of 2007, seeking to understand the importance of weather patterns on the dynamics of the disease.

3. Results

3.1. Monthly Timescales

Time series analysis of dengue incidences (Figure 1) indicate that there is a synchrony between the epidemics of Campo Grande and Maringa, occurring an average delay of one month between the epidemic peak of both, probably due to the population and economic flow between the two cities.

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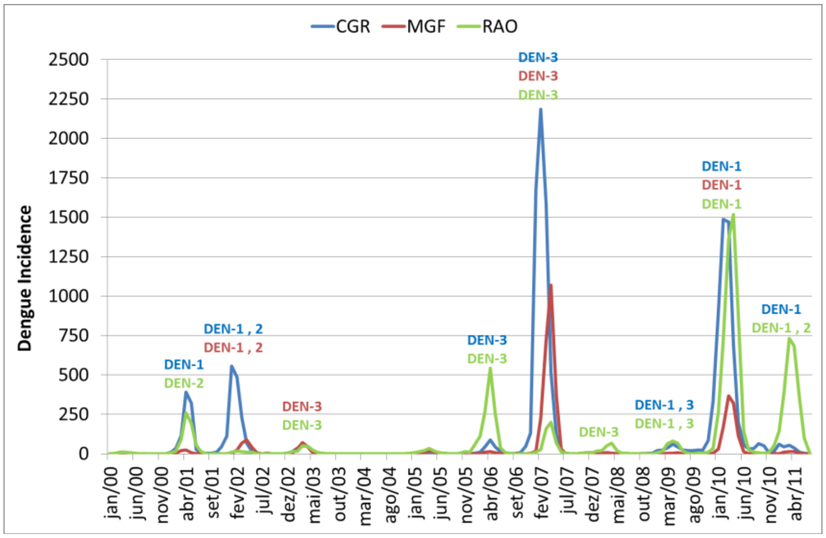

Figure 1

Epidemics and serotypes in the city of Campo Grande (CGR), Maringa (MGF) Ribeirao Preto (RAO) for the period 2000 to 2011. Source: SINAN, State Departments of Health, Ministry of Health. DEN-1, 2 and 3 indicate serotype 1, 2, and 3. Unit: cases per 100,000 habitants.

It can be seen in Figure 1 that the occurrence of new serotypes, creates epidemics due to lack of immunity in the population. We can identify the end of the epidemics of type 1 and type 2 in 2001 and the beginning of serotype 3 which peaked in 2006/2007. Following, the occurrence of type 1 after almost 10 years gap which resulted in infection of the population that had not contracted the virus at the beginning of the decade.

According to Lowe *et al.* (2010), climate seasonal forecast could have potential value in helping to predict dengue incidence months in advance in Southeastern Brazil.

The relationship between temperature (measured from MODIS LST day/night) and dengue incidences indicates that no significant correlation was found (Table 1) between positive anomalies and increased reporting of dengue fever within the period.

Table 1

Correlations between monthly temperature anomalies and dengue cases with no lag, 1, 2 and 3 months of lag.

	no lag	**1 mon lag**	**2 mon lag**	**3 mon lag**
CGR	-0.14	-0.17	-0.22	-0.14
MGF	0.10	0.09	0.16	0.16
RAO	0.03	-0.07	-0.09	-0.13

Source: IRI Library, Terra, MODIS and SINAN.

The same lack of relationship between temperature anomalies and dengue epidemics can be observed in Figure 2 (Campo Grande), Figure 3 (Maringa) and Figure 4 (Ribeirao Preto).

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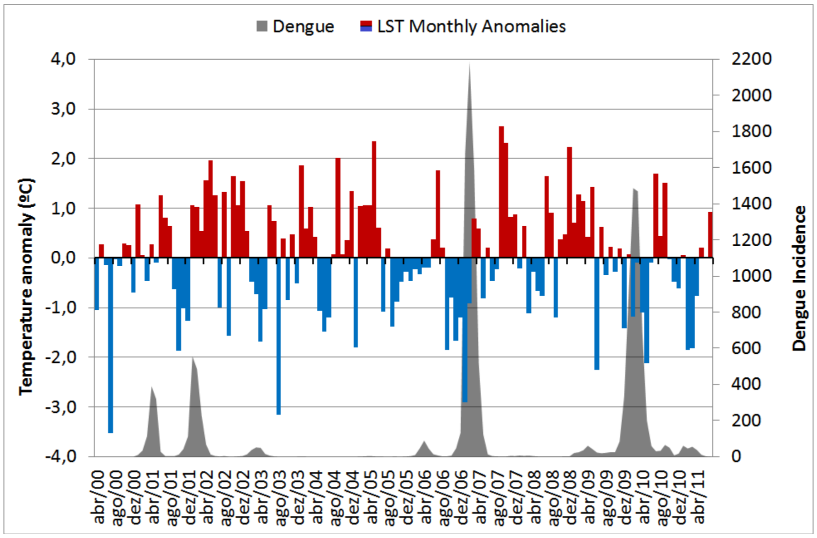

Figure 2

Temperature (LST) monthly anomaly and dengue incidence to Campo Grande.

Source: IRI Library, Terra, MODIS and SINAN.

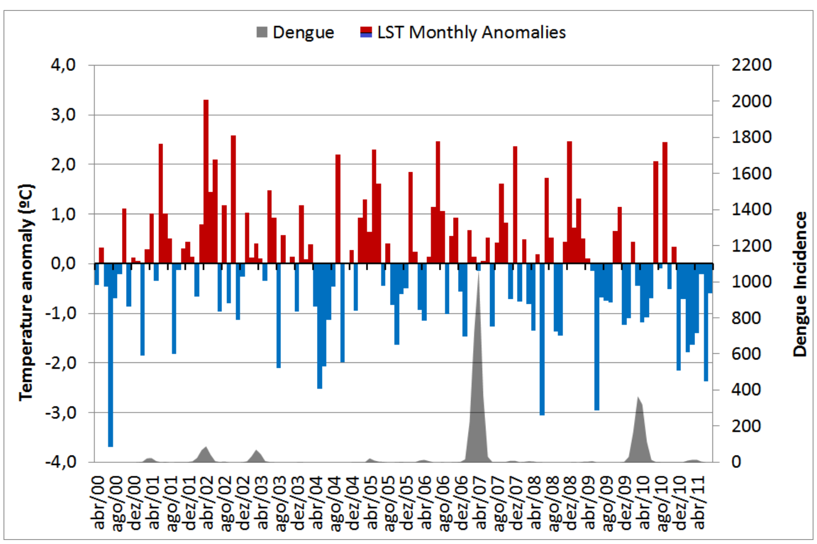

Figure 3

Temperature (LST) monthly anomaly and dengue incidence to Maringa.

Source: IRI Library, Terra, MODIS and SINAN

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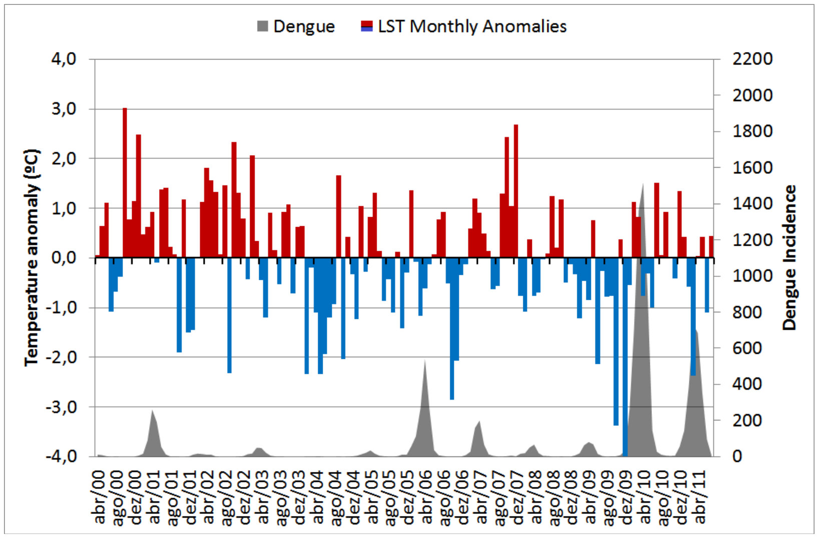

Figure 4
LST monthly anomaly by satellite (average day/night) and dengue incidence to Ribeirao Preto.
Source: IRI Library, Terra, MODIS and SINAN

3.2. Daily Timescales

The results of a rhythm analysis on daily timescale (Figure 5) show a clear relationship between temperature and reported cases of the disease. This rhythm analysis demonstrates a lag between temperature change and disease occurrence of approximately 7 days:

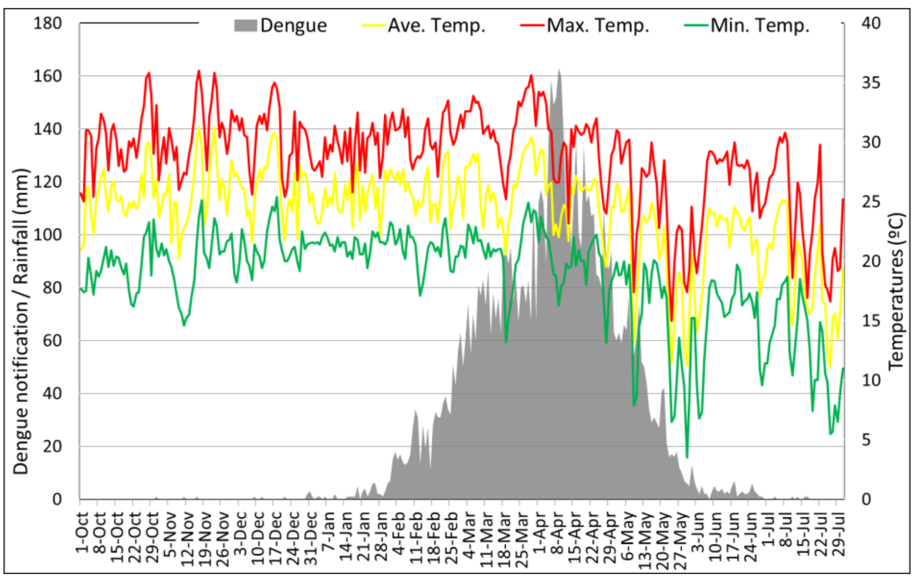

Figure 5
Temperature and Dengue cases in Maringa (Epidemic 2006-2007).
Source: INMET and SINAN.

It can be evaluated in the rhythmic analysis of Maringa that falling temperatures in mid-March 2007 (March 14) led to the stabilization of the growth of dengue cases in the city.
Soon thereafter, the disease cases increased again as temperature began rising again. The correlation between daily temperature and dengue incidence in the following week is 0.70 (P>0.99).
These findings confirm those of other studies, such as Beserra *et al.* (2006) and Lana *et al.* (2011), where the authors report the importance of temperature in the cycle of life and action of mosquito and that the lag of disease occurrence in relation to the temperature is approximately one week.

4. Discussion

Our analysis and results showed the importance of the climatic factors as well as the serotype in the occurrence of epidemics. However, it is noteworthy that the climate conditions, together with the serotype profile are not the only factors responsible for the temporal evolution of dengue. Immunity of the population and other social and environmental elements must be considered as well.

Public policy, the effectiveness of dengue control programs, limited planning and optimal resources also play a role in the manifestation of dengue. Local policies are important for controlling the disease, because through them the resources to combat dengue will be made effective.

The lifestyle of the inhabitants can also be considered as a condition for the manifestation of dengue. In particular, the disposal of trash, construction debris left in the backyards of houses or abandoned swimming pools can serve as reservoirs for mosquitos breeding. This situation was observed in several locations within the three cities, as highlighted in Figures 14a and b.

Figure 6a and 6b
Breeding sites favorable for the vector.
Source: Roseghini, W. F. F.

Another important factor favoring the circulation of serotypes and the increase of dengue cases is the mobility of the population (inter and intra-flow urban commuting). Most of notifications of imported cases in the three cities come from small cities around, because of a lack of good health assistance, forcing the population to go to the major city in the area to find hospitals and other health care services.

Socio-economic factors such as inequality and poverty also favor the flow of people from smaller cities to larger ones, both in the quest for better health services, but also to work and consume.

Campo Grande, Maringa and Ribeirao Preto are the center of their regions, and it is natural that a larger flow of people coming toward them both from neighboring towns as cities in other states.

5. Conclusion

As this is a subject of complex character, the dengue issue requires solutions that seek interdisciplinary. This research showed that climate is important for the development of epidemic disease in the three cities. Dengue epidemics occur after the rainy season when optimal conditions of temperature occurred during the period Dec-Mar.

The analysis of temperature data and dengue showed a good correlation, confirming other studies about the influence of climate in the cycle of the vector.

However, we also identified that introduction of new serotype plays a role in the development of epidemics.

We also identified the importance of other factors such as movement of population, presence of breeding sites in the cities (*e.g.* disposal of trash and abandoned swimming pools), and control strategies in place as factors that would require deeper analysis of their dynamics and impact on mosquito vector and disease transmission. It challenges scientists to achieve a better understanding of the current situation and directs them to attempt to predict the factors that are likely to favor the transmission of the disease.

In light of these issues and the challenge of the problems presented, as well as the complexity of the dengue disease itself, this research required an international and multi-disciplinary perspective with interaction between professionals from the areas of health, climate and geography which could help health sectors towards understanding dengue transmission, creating early warning systems and improving disease control actions.

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