CLIMATE DRIVES THE SEASONAL AND REGIONAL VARIATION IN DENGUE INCIDENCE IN THE MALDIVES

Foundation for Environment, Climate and Technology
C/o Mahaweli Authority of Sri Lanka, Digana Village, Rajawella,
Kandy, KY 20180, Sri Lanka

Partners

1. Water Center, Columbia University, New York, USA.
2. Foundation for Environment, Climate and Technology, Digana Village, Sri Lanka
3. Health Protection Agency
4. Maldives National University
5. Maldives Meteorological Service

Citation

Lareef Zubair[1, 2], Nishan Ahmed[3], Majeeda Mohamed[4], Zahid[5], (2017): *Climate Drives the Seasonal and Regional Variation in Dengue Incidence in the Maldives,* FECT Technical Report 2017-05, (Pages 15)

Foundation for Environment, Climate and Technology, Digana, Sri Lanka

Abstract

Dengue a mosquito borne viral disease is endemic to most tropical and sub-tropical regions in the world. The disease has been considered as a major infectious disease due to its significant morbidity and mortality. First reported in 1979, dengue has become an endemic disease in Maldives with periodic outbreaks in rainy seasons. In the Maldives Dengue has a perennial occurrence and seasonal peaks from June to August each year. A major outbreak was recorded in 2011 with 2909 cases being reported.

This study is aimed at investigating the annual, regional and seasonal variation of dengue incidents and to analyze the influence of temperature and rainfall on the transmission of dengue in the Maldivian context. The data for dengue cases in Maldives from 2000 to 2014 were obtained through the recording system of the Maldivian Ministry of Health (MMOH) and from reports across Maldives. The complied data was obtained from the Health Protection Authority (HPA). Rainfall and temperature data were obtained from Maldivian Metrological Service (MMS) and satellite based data sources. The relationship between dengue incidence and minimum temperature, maximum temperature and rainfall was quantified by region and season.

The outcome of the study revealed that the annual incidence of Dengue is bimodal with two peaks which occur as a mid-year peak in June-July and an end of the year peak in December-January. The mid-year and the end of the year peak has become more dominant in the last four years with 2011 showing a significant peak. The provinces; Upper-North, North, North Central (without Male) and Central shows a high mid-year peak in June-July while the southern provinces of South Central, Upper South and South shows a high end of the year peak. The months with the highest dengue incidence are closely clustered at a maximum temperature 30-31 °C of and a minimum temperature of 25-26 °C and dengue peaks are seen 1-2 months after the May rains. It was also observed that there is a consistent relationship between dengue incidence and climate.

Introduction

Dengue, a mosquito borne viral disease, is a disease that is endemic in most tropical and subtropical regions in the world (Schreiber, 2001: Wilder-Smith and Schwartz, 2005). Dengue is considered as one of the world's major emerging infectious diseases with a significant morbidity and mortality (Abdulla *et al.,* 2014: Wilder-Smith and Schwartz, 2005). The number of dengue cases varies from year to year and season to season and it has the possibility to reach epidemic proportions (Schreiber, 2001).

According to Moosa (2008), although 95% of global dengue burden is attributed to environmental factors such as temperature, precipitation and humidity, other factors such as change in pattern of rainfall, poor waste management and increase in migration can also result in an increase in dengue incidence. Mosquitoes are extremely sensitive to external temperature and moisture levels with temperature affecting the size of the vector and infectivity. Changes in temperature, precipitation can affect dengue incidence. But mosquitoes can adapt to adverse temperature and moisture by thriving in microenvironments such as containers and drains (McMichael *et al.,* 2003: Gagnon, Bush and Smoyer-tomic, 2001).

Dengue is a seasonal viral disease associated with more humid and warmer weather. Increase in rainfall can affect vector density and transmission potential. As these mosquitoes require stagnant water to breed, both wet and dry conditions favour the growth of the vector. Hence rainfall timing and the co-variation of other climate factors are important to study dengue incidence. Increase in temperature can reduce the time taken for vector to breed and the incubation period of the pathogen. Therefore global average temperature increase can cause a rise in dengue epidemics (McMichael *et al.,* 2003: Sirisena and Noordeen, 2014).

Maldives is a tropical country composed of 26 geographic atolls, 7 provinces (Figure 1) and nearly 1200 small coral islands. A population of about 330000 is dispersed over 200 of these small islands, which extends to a length of 820 km and has a width of 120 km. All the islands are low lying with an elevation of about 3 m above the sea level (Ahmed, 2007: Afeef and Shaheem, 1999). Maldives, an archipelago in the Indian Ocean, has an average year around rainfall between 1600-1900mm contributed by the south-west (May-August) and north-east (October-

January) monsoons. Maldives has a hot and humid climate with a temperature between 25°-31°C and humidity between 70%-90%, throughout the year (Afeef and Shaheem, 1999).

First reported in 1979, dengue is now an endemic disease in Maldives with periodic outbreaks in rainy seasons. Dengue has a perennial occurrence and seasonal peaks from June to August each year. (Abdulla *et al.,* 2014: Ahmed, 2007). According to the Annual Communicable Diseases report (2012 and 2013), 681 cases were reported in 2013 and 1083 cases were reported in 2012, while a major outbreak was recorded in 2011 with 2909 cases being reported. Dengue was the fourth most commonly notified disease in 2011 (Abdulla *et al.,* 2014). The report also states that dengue cases increase in early January and between June-July in the wet season. In 2012, most cases were reported from Male', Hulhumale', Alif Dhaal, Haa Dhaal and Meemu atolls. And in 2013, most cases were reported from Male', Hulhumale', Alif Dhaal, Noonu, Baa, Ali Alif, Alif Dhaal, Dhaal, Thaa, Gaafu Alif, Gaafu Dhaal and Seenu atolls.

During this study we investigate the annual, regional and seasonal variation of dengue incidence and we analyse the influence of temperature and rainfall on the transmission of dengue in Maldives.

Data and Analysis

The population data was obtained from the Department of Census. The data for dengue cases in Maldives from 2000 to 2014 were obtained through the recording system of the Maldivian Ministry of Health (MMOH) from reports across Maldives. And the compile data was obtained from the Health Protection Agency (HPA). Rainfall and temperature data were obtained from Maldivian Meteorological Service (MMS) and satellite based data sources.

These data were then used to evaluate the annual, seasonal and regional variation of dengue incidence in Maldives. The relationship between dengue incidence and minimum temperature, maximum temperature and rainfall was quantified by region and season, based on the observations by the HPA and MMOH. The annual, regional and seasonal variation of dengue incidence in Maldives was studied initially using different graphs in order to evaluate the seasonal relationship between temperature, rainfall and dengue incidence.

To display the seasonal pattern of dengue incidence, the number of dengue cases over a period of ten years were aggregated and plotted by month. Regional variation of dengue incidence was analysed by dividing the monthly aggregate of cases for a province by the population of the province and multiplying by 10000. The peak months for dengue incidence and the climactic variables (precipitation, maximum and minimum temperature) were obtained by plotting the monthly averages of the variables for all the seven provinces. These peak months were then analysed against the latitude of the provinces. Thus the temporal pattern of the monthly dengue cases and climatic averages were examined using graphs to study the seasonality of dengue and climate.

Results

The population data was used to create a line chart to study the trend of population size from 2000 to 2014.

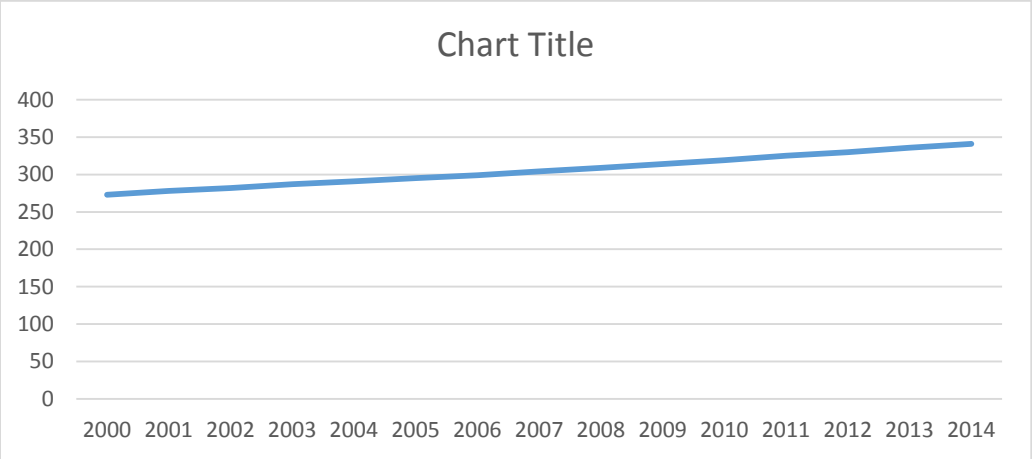

Figure 1: Temporal variation of population size over the study period

Annual cycle of dengue incidence in Maldives

Dengue incidence data from 2000 to 2014 was used to evaluate the occurrence of dengue in Maldives. The annual incidence of Dengue is largely bimodal with two peaks (Figure 2). The two peaks of annual dengue incidence in Maldives occur as a mid-year peak in June-July and an end of the year peak in December-January (Figure 3). The mid-year and the end of the year peak

have become more dominant in the last four years with 2011 showing a significant peak. In the years 2009 and 2010, a decrease of incidence is observed (Figure 4).

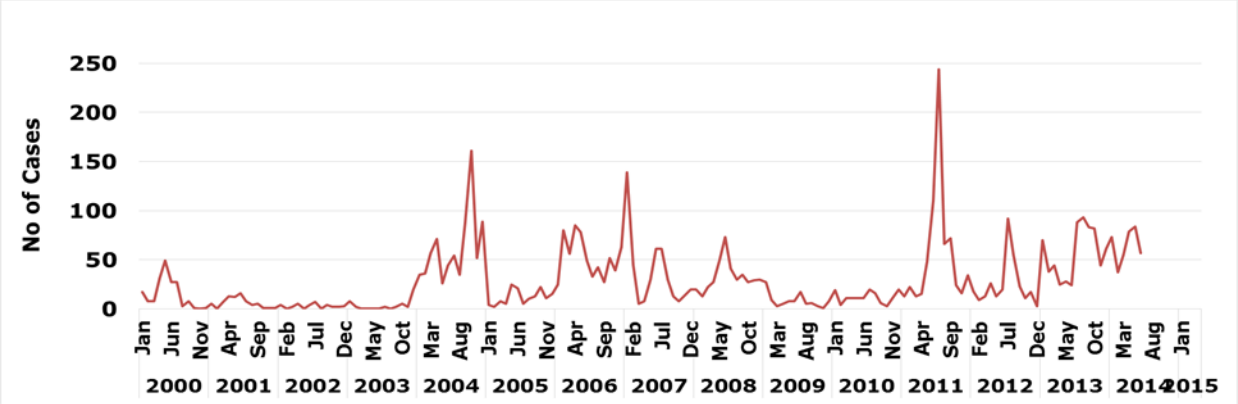

Figure 2: Dengue cases in Maldives from 2000 to 2014

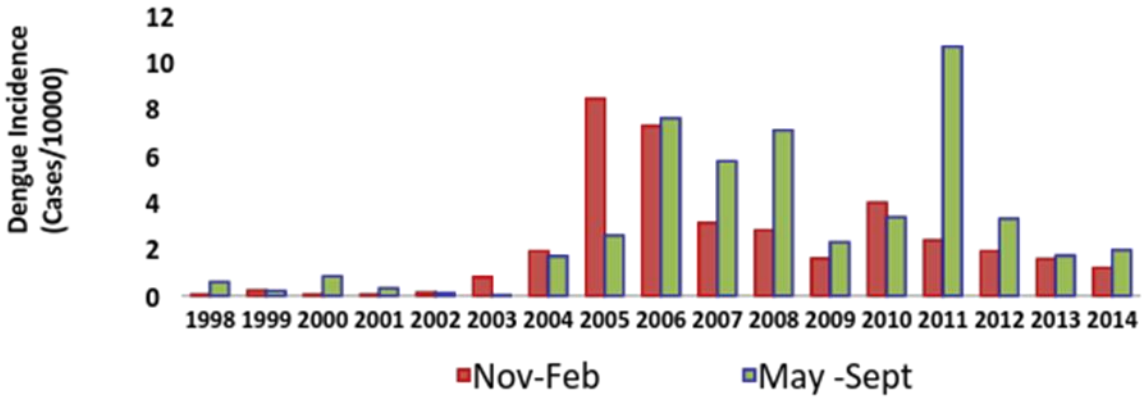

Figure 3: Inter-annual variation of seasonal dengue incidence in Maldives

Regional variation of dengue incidence in Maldives

The two peaks of annual incidence are observed in all the seven provinces (Upper-North (UNP), North (NP), North Central (without Male) (NCP), Central (CP), South Central (SCP), Upper South (USP) and South (SP)) and Male. In addition to the two peaks of annual incidence, certain

provinces display dengue peaks in other months as well. Frequent peaks in dengue incidence can be observed throughout 2005 to 2008 in each province, with the most significant peak in 2011. The rise of dengue incidence is very low in 2009 and 2010 within the provinces (Figure 5).

UNP and NP has a lesser mid-year peak when compared to the other provinces. While NCP and CP shows the highest peaks and USP, SCP and SP shows a peak, higher than UNP and NP but lesser than NCP and CP (Figure 7). The mid-year peak is always higher than the end year peak in all the provinces except the two provinces NP and SCP (Figure 6), which shows a higher end year peak.

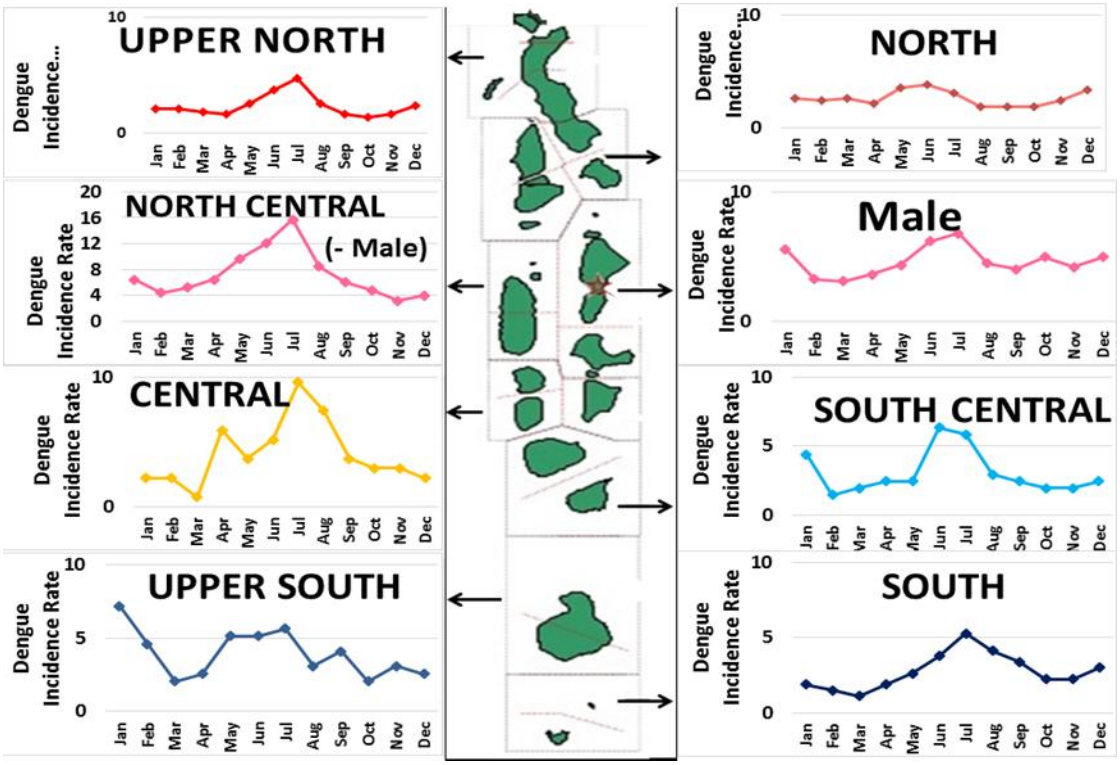

Figure 4: Seasonality of regional dengue incidence in Maldives

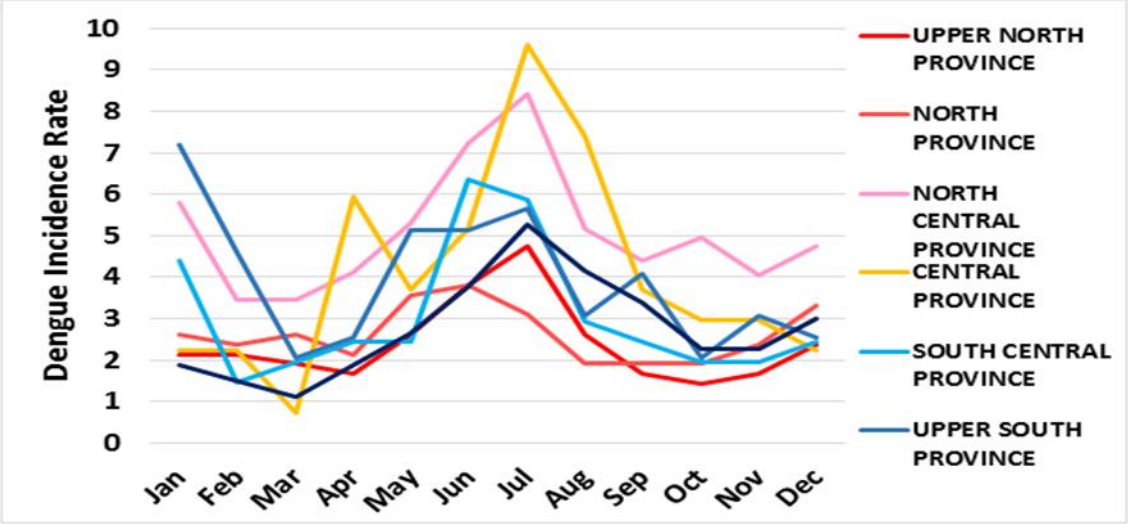

Figure 5: Comparative seasonality of regional dengue incidence in Maldives

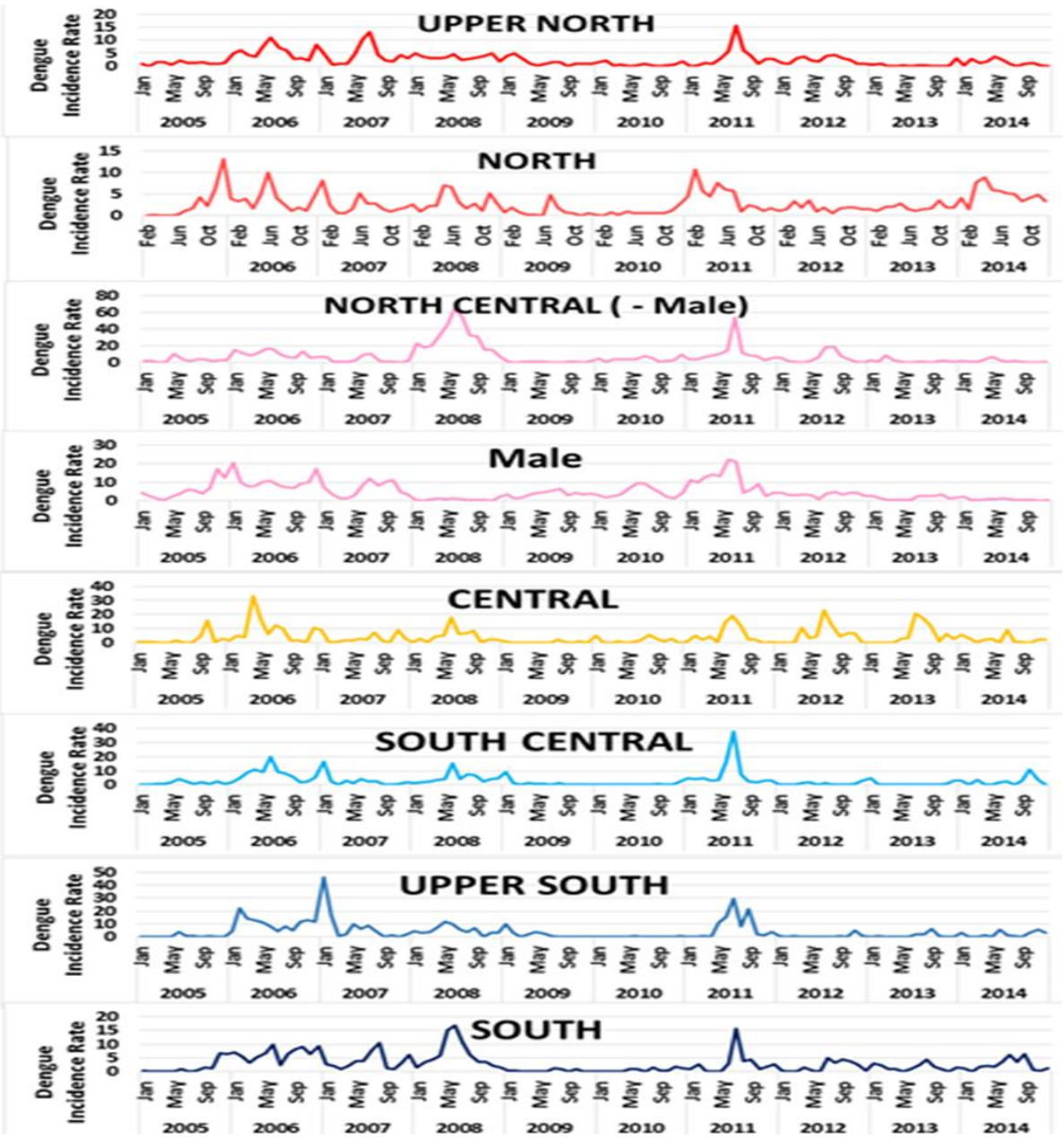

Figure 6: Inter-annual variation of dengue incidence from north to south

Seasonality of dengue and climate

The monthly average incidences of dengue for the seven provinces are shown as a black line in the graphs (Figure 7). The monthly average rainfall is shown as grey shading and minimum and maximum temperature is shown as bar graphs.

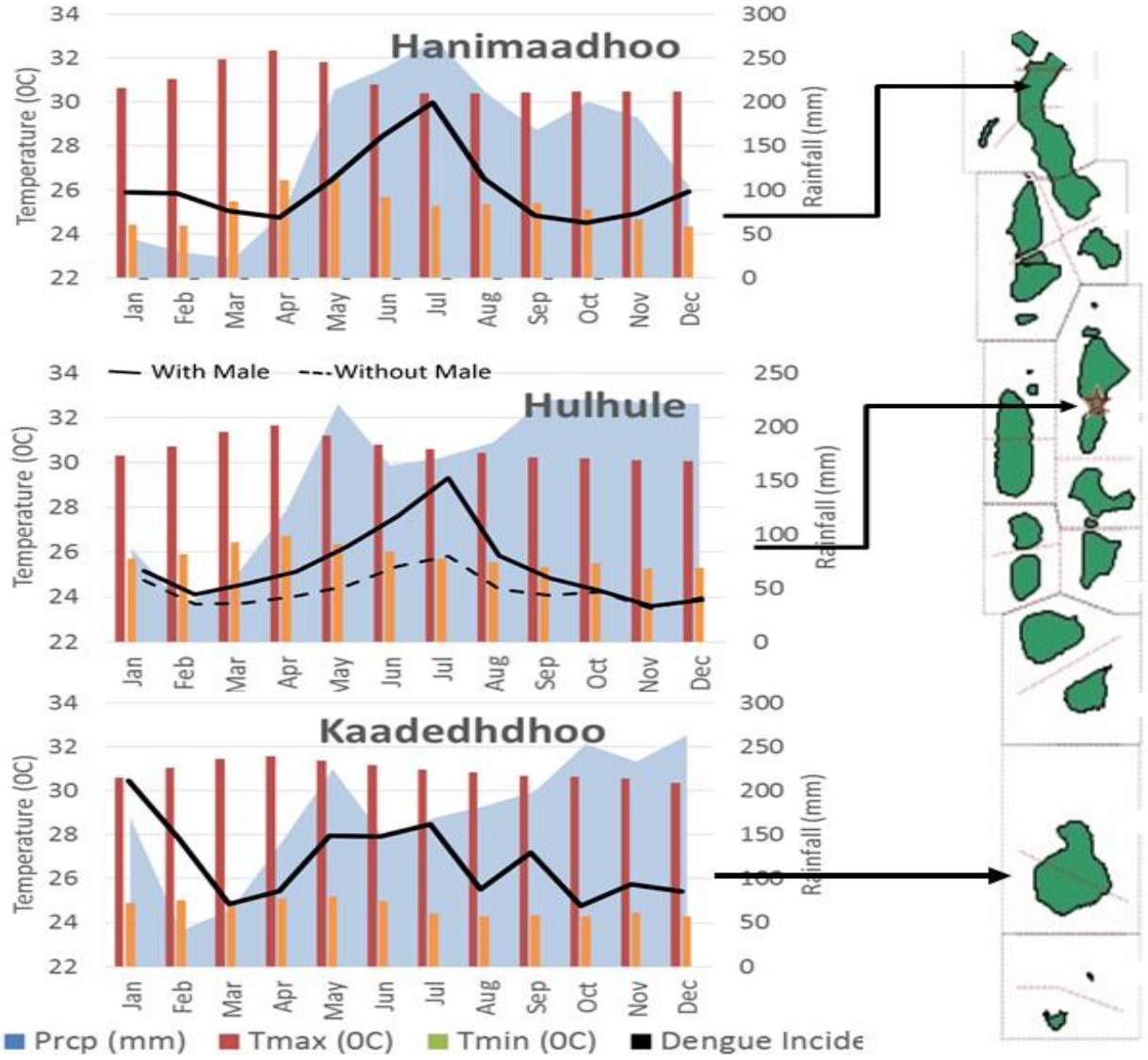

Figure 7: Seasonality of dengue incidence and climate

According to the above graphs the months with the highest dengue incidence are closely clustered at a maximum temperature 30-31 °C of and a minimum temperature of 25-26 °C. The peak months for rainfall is May and October and the peak months for maximum and minimum temperature are March and May in Maldives. Exceptions were observed with several provinces showing a peak in months other than the above, which are highlighted and shown in Table 2.

Discussion

Dengue is emerging as a major public health concern in Maldives with an increase in incidence in recent years. A widespread dengue outbreak was witnessed in 2011 in Maldives with a decline in incidence in the years 2009 and 2010. Even though the two main dengue peaks are in the months of June-July and December-January, peaks were also observed in certain other months. As dengue is known to be unpredictable with regard to its incidence, it is difficult to derive any conclusions from this (Mohd-Zaki *et al.,* 2014).

The difference of dengue peaks for Northern and Southern provinces may be due to the variation of the regional climate. Although Maldives has a small land area, the climate mechanisms change drastically from North to South with the northern islands displaying a climate similar to India and southernmost islands showing a climate similar to the Southern hemisphere.

Based on the analysis of the climate and incidence data there are clear evidences of climate drivers of dengue seasonality. The two annual peaks of dengue are seen during the south-west and north-east monsoon seasons. And dengue peaks approximately 1-2 months after the peak in rainfall. Dengue transmission and temperature has a positive co-relation with high incidence being reported at a temperature of 31°C. Hence dengue incidence and climate shows a consistent relationship across regions and seasons. Rainfall and temperature relationships with dengue persist in different regions even while the seasonality changes. These relationships are much more sensitive than may be understood from laboratory studies. We need further analysis at shorter time steps to nail down the relationships with rainfall.

Conclusion

There is a consistent relationship between dengue incidence and climate. Dengue incident in Maldives shows two annual peaks: a mid-year peak in June-July and an end of the year peak in December-January. While most of the provinces show a high mid-year peak, the southern provinces show a high end of the year peak. When dengue incident from 2000 to 2014 is considered, the two peaks were dominant in the last four years with 2011 showing a significant peak, while a lesser incidence was observed in the years 2009 and 2010. Dengue incident shows a clear association with rainfall and temperature across regions and seasons. Months with the highest dengue incidence shows a minimum and maximum temperature between (25-26) °C and (30-31) °C.

Dengue incident is unstable over the period analyzed – there are sharp rises in cases in some years followed by precipitous drops. In an aggregate sense, the mid-year peaks dominate in some years such as 2011 and the end of the year peak dominates in 2005. However, with the available data, we can still provide evidence for a seasonal and regional relationship in dengue incidence and climate.

We find that dengue occurs all across the Maldives and its seasonality is closely tied to the seasonality of the regional climate. On an annual scale, the peak incidence takes place in the north-central islands around Male.

The monthly average Dengue incident across Maldives shows a bimodal character with a mid-year peak in June-July and an end of the year peak in December-January. The Maldives is generally arranged as a sequence of islands from North-South. In general, the mid-year peak is dominant in the Northern Provinces, while the end of the year peak becomes dominant towards the Southern region.

This variation in dengue incident is consistent with the modulation of peaks in the bimodal rainfall climate across the country – the rainfall in the Northern Islands are dominated by the heavy rainfall in the mid-year (May to September) and that of the Southern islands are dominated by heavier rainfall October to December. The dengue incidence peaks follow that of rainfall typically by 2 months.

The seasonal variation in temperature is subtle but still influential on the dengue transmission dynamics. Months with the highest dengue incidence shows a minimum and maximum temperature between (25-26) °C and (30-31) °C. Dengue peaks follow lag of two months of the temperature peaks. The transmission is coincident with lower temperatures.

Nevertheless dengue has the likelihood to peak throughout the year. The mid-year peak is always higher than the end of the year peak in most provinces and the strength of the peak increases with the decrease in the latitude. When dengue incidence from 2000 to 2014 is considered, the two peaks were dominant in the last four years with 2011 showing a significant peak, while a lesser incidence was observed in the years 2009 and 2010. There is a consistent relationship between dengue incidence and climate. Dengue incidence shows a clear association with rainfall and temperature across regions and seasons.

References

Abdulla, A.A., Rasheeda, F., Ahmed, I.N. and Aboobakur, M. (2014) 'An evaluation of the surveillance system for dengue virus infections in Maldives', WHO South-East Asia Journal of Public Health, 3(1), pp:60-68.

Ahmed, N. (2007). *Knowledge, attitude and practice of dengue fever prevention among the people in Male', Maldives.* Masters. Chulalongkorn University

Gagnon, A.S., Bush, A.B.G., Smoyer-Tomic, K.E. (2001) 'Dengue epidemics and the El Niño Southern Oscillation', *Climate Research,* 19(1), pp:35–43. Available at: https://www.ualberta.ca/~abush/clim.res2001.pdf

Health Protection Agency (2012) Annual Communicable Diseases Report. [pdf].

Health Protection Agency (2013) Annual Communicable Diseases Report. [pdf].

McMichael, A.J., Campbell-Lendrum, D.H., Corvalan, C.F., Ebi, K.L., Githeko, A.K., Scheraga, J.D. and Woodward, A. (2003). Climate change and human health. Geneva: World Health Organisation.

Mohd-Zaki, A.H., Brett, J., Ismail, E. and L'Azou, M. (2014) 'Epidemiology of Dengue Disease in Malaysia (2000–2012): A Systematic Literature Review', *PLoS Neglected Tropical Diseases*, 8(11): e3159. Available at: http://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0003159#s5

Moosa, S. (2008) 'Adaptation measures for human health in response to climate change in Maldives', *Regional Health Forum,* 12(1), pp:49-55.

Schreiber, K.V. (2001) 'An investigation of relationships between climate and dengue using a water budgeting technique', *International Journal of Biometeorology*, 45: pp:81-89.

Sirisena, P.D.N.N. and Noordeen, F. (2014) 'Evolution of dengue in Sri Lanka—changes in the virus, vector, and climate', *International Journal of Infectious Diseases*, 19, pp:6-12. Elsevier. Available at: http://dx.doi.org/10.1016/j.ijid.2013.10.012

Wilder-Smith, A. and Schwartz, E. (2005) ‘Dengue in Travelers’, *The New England Journal of Medicine*, 353: pp:924-32.