Ramification of Global and Local Climatic Variability on Resurgent Cases of Dengue in Delhi, India

Sahu Netrananda* **and Mishra Martand Mani**
Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, INDIA
*babunsahu@gmail.com

Abstract
It has become evident that the global climate is changing rapidly over the past few decades. The variation and change in the global climatic factors have a notable impact on the local climate of a region. The changing climate is widely regarded as one of the most serious global health threats of the 21st century. Among various kinds of diseases, the most vulnerable to these changes are vector-borne diseases. In the Indian context, particularly Delhi city is the most vulnerable to dengue, a kind of vector-borne disease having its highest impact. We sought to identify and explore the correlation and influence of the global climatic phenomena and local climatic factors with the reported number of dengue cases in Delhi.

The temporal expansions of reported dengue cases in Delhi have a variation from its first major outbreak in the city during the year 1996 to 2015. A statistical tool like Pearson Product Moment Correlation (PPMC) is used in this study to establish the interrelationship and the level of impact and local climatic variation on dengue. An exceptional negative correlation value of r = -0.82 between the monsoon index and the dengue incidences was reported during the positive years and also maintains a very high positive correlation with other global climatic indices. The study here finds that there is a strong correlation of climatic variation which further influences the epidemiology of dengue in Delhi.

Keywords: Delhi, Climatic Variability, Dengue, ENSO, ISMR.

Introduction

The unprecedented variations and change in the climatic factors have some very serious impact on human health[24, 25]. The changing pattern of the climate regulates the range of infectious ailments whereas the variability determines its timing and intensity of impact[5]. Specifically, vector-borne diseases are very case sensitive to global as well as local climatic factors. Among the vector-borne diseases, dengue continues to be the most dominant and is highly influenced by the variability and changes in the climatic factors.[28] According to World Health Organization, dengue fever and its various forms have become a matter of international public health priorities and concerns. Dengue fever is a kind of mosquito-borne disease caused by the dengue virus. In many countries of the subtropical and tropical regions, dengue is a major public health concern mainly impacting the urban and semi-urban areas[4].

It is considered that the incidence of dengue cases has a high correlation with climatic factors including temperature, rainfall and humidity leading to the advancement and upsurge in the case[32,33]. The spread and distribution of the disastrous vectors are highly determined through temperature and rainfall[27]. Variation and changes in the temperature lead to shifting in the geographical radius of the vectors, their biting rate and incubation period[8]. Fluctuation in the rainfall amount and duration are also of high importance to the dengue infection. Rainfall has both a positive as well as a negative impact on the demography of mosquitoes, as rising in the rainfall will lead to an increase in the geographical extent of the larval habitat whereas excess rainfall will lead to flush of the eggs that will harm their population[12,23].

Therefore, in the current study, anomalous monthly temperature, rainfall, humidity and a total number of rainy days are taken as local climatic factors to see in-depth association with the number of dengue cases registered in Delhi city during the years which have shown a positive growth rate from 1996 to 2015.

Dengue is an endemic vector-borne infection in India and it is known for over two centuries[9,15]. Among several cities of north India, in Delhi particularly for the last two decades, dengue has become frequent and rampant and its ramification on the city population is of serious concern for scientists, policymakers and researchers. The resurgence of dengue cases is contributed to the demographic changes and uncontrolled increase in urbanization. Climatic and non-climatic factors influence the dengue epidemiology uniquely in different geographical entities[22] and it is very strenuous to ignore the impact of geographical and climatic factors which leading to a rapid increase in the disease infection. Numerous previous and recent research studies have described well the ramification and correlation of climatic factors with dengue.[11,18,26]

Looking at the previous history of dengue cases, it can be the inference that it is representing a seasonal trend. It has been observed that dengue infection has a high impact from the pre-monsoon season to the post-monsoon season[13,14]. The local climatic factors are highly influenced by oceanic and atmospheric phenomena. The direct impact of these global climatic factors influences the local weather condition that as an ancillary leads to dengue transmission. Therefore we have taken the climatic indices of ENSO (El Nino/Southern

Oscillation), IOD (Indian Ocean Dipole) and ISMR in this study.

Material and Methods

Study Area, Dengue Cases and Local Climate data: The study area Delhi is located in India at 28.61^0 N and 77.23^0 E lying in the northern part of India. The dataset used in the study is obtained from secondary sources. We used the yearly data of dengue from (1996 – 2015) provided by the National Vector Borne Disease Control Board (NVBDCB) of Delhi for looking into the surging cases of dengue and its relationship with local and global climatic factors. Monthly data on the local weather comprising factors like rainfall, temperature, humidity and rainy days were acquired from the Directorate of Economics and Statistics, Government of Delhi and Regional Metrological Department, New Delhi.

Ocean Climate data: Several studies have documented that the increased incidences of dengue cases have an association with ENSO[6,10]. Different climatic indices have been used in the study which have their origin in the Pacific and the tropical Indian Ocean to look at their association with the yearly incidences of dengue infection. The climatic indices taken for the study are El Niño Modoki Index (EMI), Niño 3.4, Ocean Niño Index (ONI) (ENSO indices) and Dipole mode index, (DMI) from the Pacific ocean whereas Monsoon Index(MI) is from the Indian Ocean region. The EMI in equation 1 is calculated as:

$$EMI = (SSTA)_A - 0.5\ (SSTA)_B - 0.5\ (SSTA)_C$$

where SSTA indicates sea surface temperature anomaly over each of the region A (165^0 E–140^0 W, 10^0S–10^0N), B (110^0W–70^0W, 15 ^{0}S–5 ^{0}N) and C (125 ^{0}E – 145 ^{0}E, 10 ^{0}S–20 ^{0}N) respectively[3]. The ONI is the measurement of running three months SST in Niño 3.4 region (5°N - 5° S, 120° W - 170° W) and the data for the same is obtained from Climate Prediction Centre, National Oceanic and Atmospheric Administration (CPC, NOAA). DMI is defined as the difference between the SST anomaly of the region lying within (50° E - 70° E, 10^0 S - 10^0 N) and (90° E - 110° E, 10° S – Equator) [30]. The monthly data for DMI is obtained from the online portal of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Indian summer monsoon rainfall index (ISMR) is obtained from the mean zonal wind Southern (40°E-80°E, 5°N-15°N) and Northern (70°E-90°E,20°N-30°N) [36, 37].

Statistical Analysis: The mean for twenty years starting from 1996-2015 of annually reported dengue cases is calculated to find out the percentage growth during the years. The percentage growth rate is calculated by applying the formula:

$$\text{Percentage Growth rate of Dengue cases} = \frac{A - \bar{A}}{\bar{A}} * 100$$

where A= Number of Cases in a particular year and $\bar{A}$ = Average of the total number of cases from 1996 to 2015.

Positive years are taken for the detailed analysis in this study. Further the anomalous of local weather factors for every month of twenty years is calculated. Mean of anomalous value for the 20 years, during the positive years for months (May to December) and seasons (MJJ, JJA, JAS, ASO, SON, OND) mean value starting from (June to November) are also calculated. In the same way for the global climatic factors, mean of months (May to December) and seasons mean (June to November) is calculated.

The linear relationship between the climatic factors (local and global) and the number of cases reported are examined by the Pearson Product Method Correlation (PPMC) analyses. The detailed impacts of climatic factors are investigated and they reveal that there is a very strong correlation between these factors during certain seasons of high dengue cases.

Results

The location of the study area, the total number of dengue cases from 1996 to 2015 and its annual growth rate have been shown in figure 1. It is observed through the calculation that the years 1996, 2003, 2006, 2010, 2013 and 2015 are showing positive growth in the dengue cases while the linear trend of the dengue infection is showing an increasing trend (Figure1b). If we look at the years when growth is positive, it is highest during the year 2015 whereas it is lowest positive in 2003 (Figure 2b).

In this study, we have focused on the + growth year and attempted to establish the linkages between the climatic factors and their growth. There is enough documentation regarding the corroboration of dengue cases and climatic factors for the city Delhi. The impact of local and global climatic factors on the number of dengue cases is examined through PPMC. The tropical climatic modes have an impact on the local climatic which may have direct consequences on the spread of dengue cases.

Local Climatic factors: Dengue infection immensely relies on the local weather systems including temperature, rainfall and relative humidity**.** Seasonal anomalous of temperature, rainfall, humidity and the number of rainy days is taken into account as local climatic factors for calculating PPMC to reported + year dengue cases. The seasons selected for the study are May-June-July (MJJ), June- July- August (JJA), (July- August- September) JAS, August-September-October (ASO), September-October-November (SON) and October-November-December (OND) as the cases are reported maximum from June to November.[7,31]

These seasons are representing the pre-monsoon to the post-monsoon period. From 1996 to 2015, among the local climatic factors for selected months of study (May to December), temperature and relative humidity anomaly is showing an increasing trend while anomalous of rainfall and rainy days is reflecting the negative trend (Figure 2a, 2b, 2c, 2d).

The +years of dengue cases PPMC calculation with local climatic factors are showing some very interesting and significant relationship as in table 1. Rainfall, relative humidity and rainy days show the comparatively high value of PPMC – 0.74, - 0.77 and – 0.50 respectively than the temperature which is showing very low positive PPMC value of 0.02 (Figure 3a).

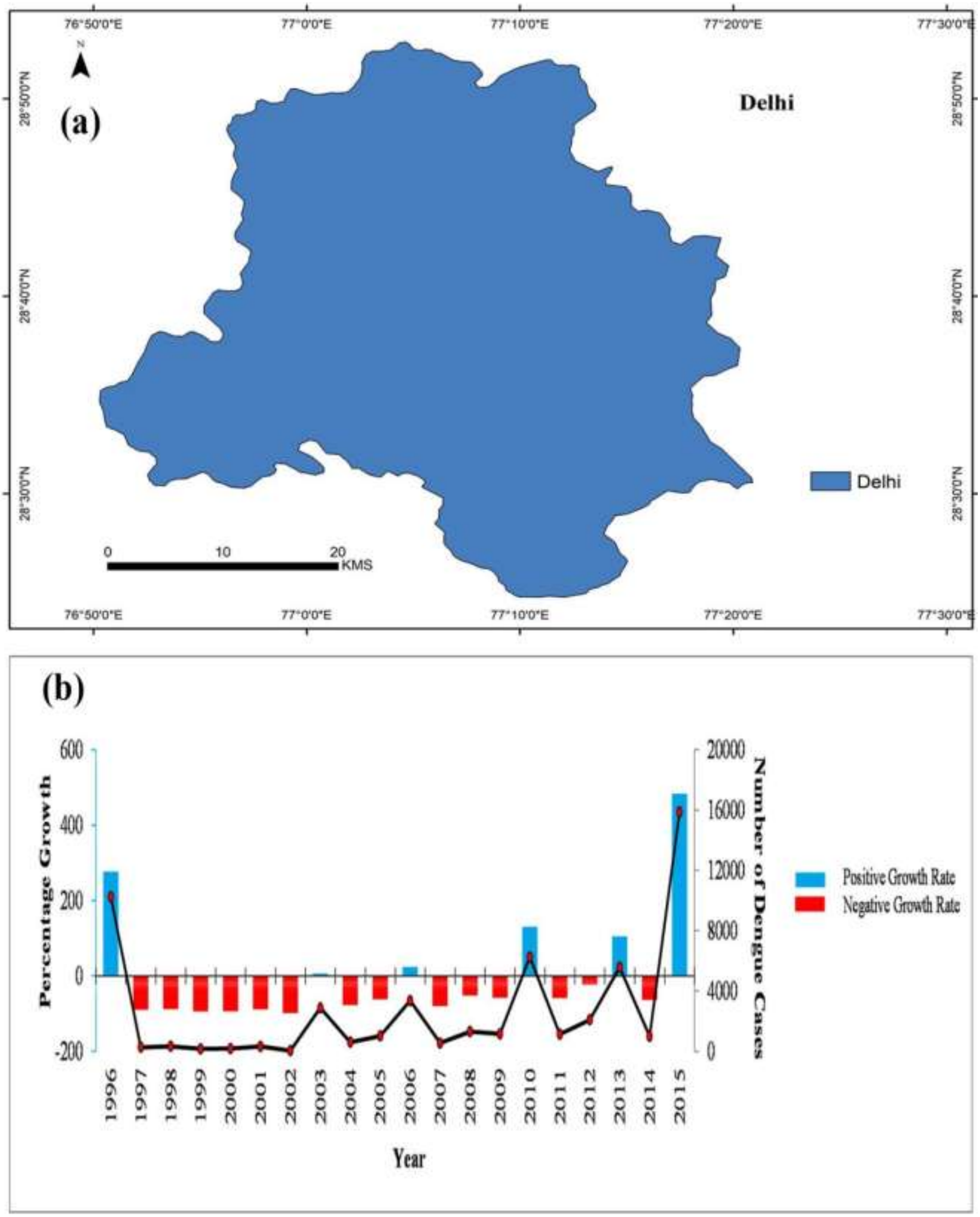


Figure 1: (a) Locational map of the study area (b) the time series plot for a number of reported dengue cases and percentage growth from 1996 to 2015

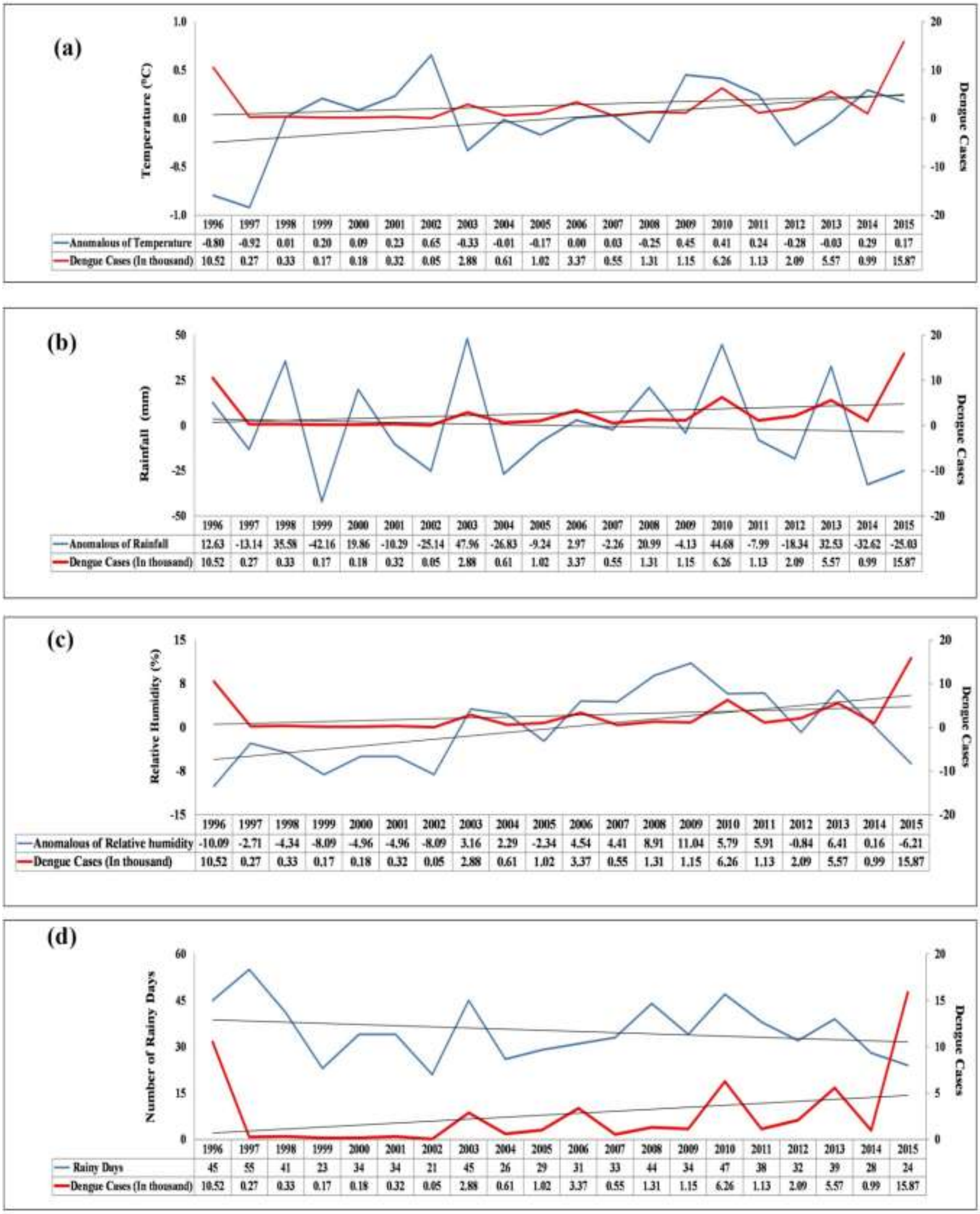


Figure 2: Time series plot and trend line of local climatic factors and an annual number of dengue cases (in thousand). The average anomaly is calculated for the month May to December for (a) temperature (b) relative humidity (c) rainfall. Figure (d) represents total number of rainy days from May to December recorded in each year taken for looking at the trend. The red color line is showing the reported dengue cases whereas blue color line is used for the local climatic factors

Throughout the monsoon season (MJJ, JJA and JAS) in the + years, it can be observed that rainfall and relative humidity are very highly dominating factors (r = -0.65, -0.64 and -0.56) and (r= -0.66, -0.74 and -0.83) respectively (Figure 3b). During the monsoon season, low amount of rainfall, relative humidity and a lesser number of rainy days play a very vital role in surging the number of reported dengue cases.

While in the post-monsoon season, our result is reflecting the dominance of relative humidity combined with temperature for the ASO, SON and OND seasons (Figure 3b). Temperature is positively correlated whereas in the case of relative humidity it is continuing its inverse relationship. The highest PPMC for temperature is observed in the SON followed by ASO and OND (Figure 3b) in post-monsoon season. The r = - 0.82 is the highest value for humidity observed during the ASO period followed by SON and OND (Figure 3b) during the post-monsoon period. It is highly negative for relative humidity throughout the monsoon and post-monsoon season. After the monsoon season ends, the amount of rainfall decreases which helps temperature to play its positive role coupled with the low relative humidity for providing breeding ground to mosquitoes.

Therefore, it can be inferred from the result that in Delhi, among the local climatic factors, rainfall and relative humidity are highly dominant elements in which a minor variation can lead to an outbreak of the disease during May to August (monsoon season) whereas the case is the same for temperature and humidity but for the month September to December (post-monsoon season). It is interesting to observe that rainy days are playing an important role in the beginning as well as in last season as it influence the amount of humidity and rainfall.

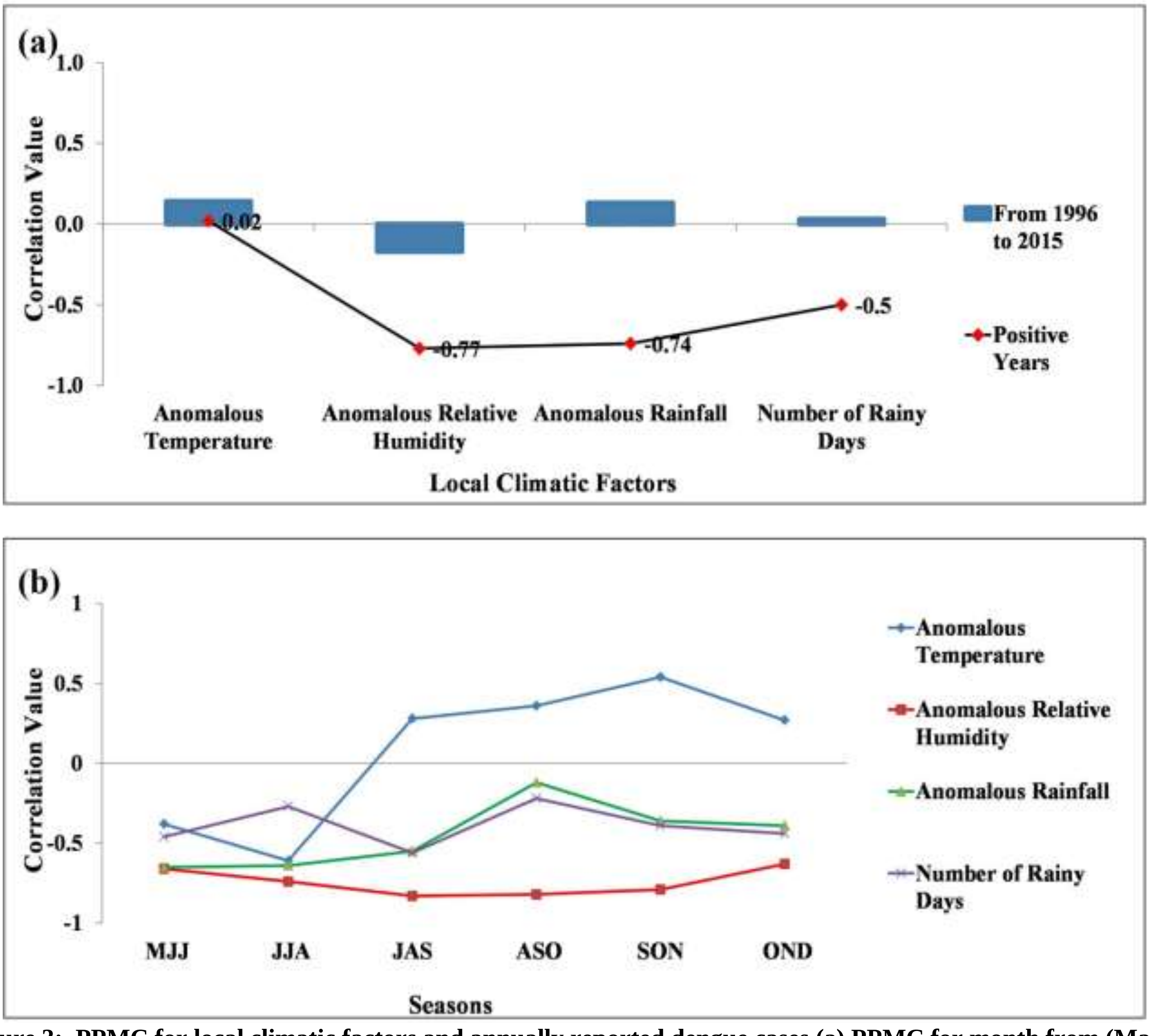


Figure 3: PPMC for local climatic factors and annually reported dengue cases (a) PPMC for month from (May to December) average anomaly for temperature, relative humidity, rainfall, number of rainy days and dengue cases for 1996 to 2015 and during + growth years (b) seasonal (MJJ, JJA, JAS, ASO, SON, OND) PPMC with dengue incidences during the + growth years

Table 1
Seasonal and monthly (May to December) correlation of different local climatic factors with dengue cases

Time Series Seasonal Correlation for 1996 to 2015						
Seasonal Correlation Value During the + Years (1996, 2003, 2006, 2010, 2013 and 2015)						
Climate factors	**Correlation with MJJ**	**Correlation with JJA**	**Correlation with JAS**	**Correlation with ASO**	**Correlation with SON**	**Correlation with OND**
Temperature	-0.38	-0.61	0.28	0.36	0.54	0.27
Relative Humidity	-0.66	-0.74	-0.83	-0.82	-0.79	-0.63
Rainfall	-0.65	-0.64	-0.56	-0.12	-0.36	-0.39
Rainy Day (Total no. of days)	-0.46	-0.27	-0.25	-0.22	-0.39	-0.44

Correlation During the Peak Months of Dengue Cases (May to December) Value (May to December)	
Climate factors	**Positive Years**
Temperature	0.02
Relative Humidity	-0.77
Rainfall	-0.74
Rainy Day (Total number of days)	-0.50

Table 2
Seasonal and monthly (May to December) correlation of different global climatic factors with dengue cases

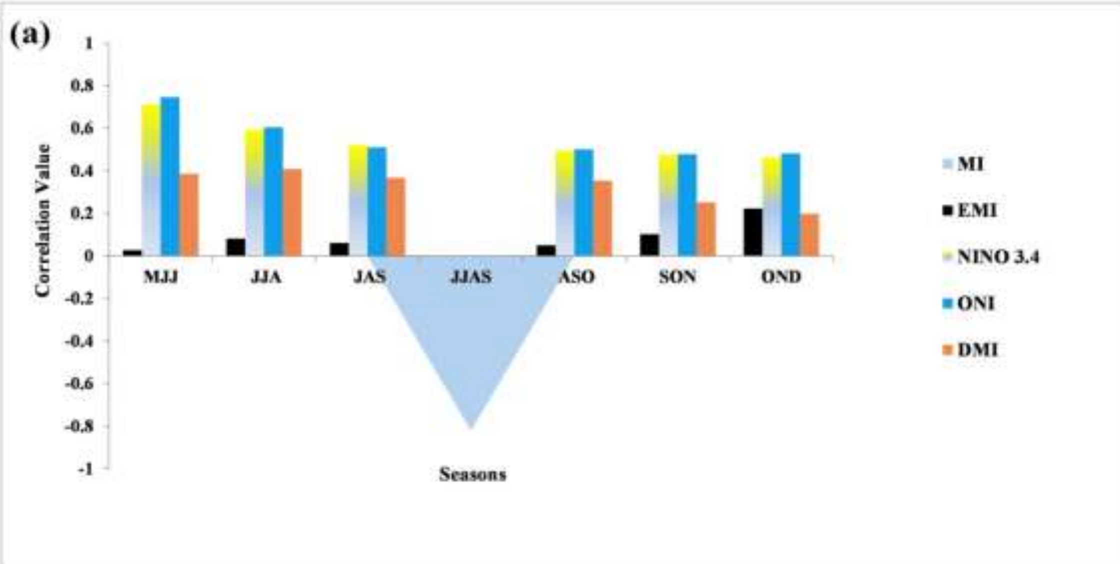
Time Series Seasonal Correlation for year (1996 to 2015)							
Climatic Indices	**Correlation With MJJ**	**Correlation Value for JJA**	**Correlation Value for JJAS**	**Correlation Value for JAS**	**Correlation Value for ASO**	**Correlation Value for SON**	**Correlation Value for OND**
EMI	0.252	0.182	-	0.089	0.058	0.088	0.178
MI	-	-	-0.234	-	-	-	-
ONI	0.275	0.225	-	0.205	0.232	0.234	0.273
Niño 3.4	0.259	0.229	-	0.219	0.229	0.243	0.262
DMI	-0.093	-0.048	-	-0.022	-0.020	-0.065	-0.064
Seasonal Correlation Value During The + Years (1996, 2003, 2006, 2010, 2013 and 2015)							
Climatic Indices	**Correlation With MJJ**	**Correlation Value for JJA**	**Correlation Value for JJAS**	**Correlation Value for JAS**	**Correlation Value for ASO**	**Correlation Value for SON**	**Correlation Value for OND**
EMI	0.027	0.080	-	0.060	0.049	0.102	0.222
MI	-	-	-0.8275	-	-	-	-
ONI	0.745	0.604	-	0.509	0.500	0.478	0.481
Niño 3.4	0.710	0.591		0.520	0.493	0.475	0.462
DMI	0.385	0.407	-	0.367	0.353	0.251	0.198

Correlation During the Peak Months of Dengue Cases (May to December) Value		
Climatic Indices	**May to December**	
	From 1996-2015	**Positive Years**
EMI	0.18	0.13
ONI	0.26	0.54
Niño 3.4	0.26	0.53
DMI	-0.03	0.09

Global Climatic factors: The PPMC between global climatic factors and dengue infection in Delhi for the study year 1996 to 2015 during the months (from May to December) appeared tenuous as the highest interrelationship is observed with Niño 3.4 followed by ONI, EMI and DMI as in table 2. During + growth years, ONI and Niño 3.4 are having high r = 0.54 and 0.53 respectively while DMI and EMI are showing very negligible interconnection with the reported infection in table 2. Further, in the study, we have calculated the linear coefficient correlation of reported dengue cases for the seasons taken in the study during + years with the global climatic factors including ONI, Niño 3.4, DMI and monsoon index (MI) as in table 2.

The seasonal value of the other two ENSO indices (Niño 3.4 and ONI) is showing the strongest influence in almost all the seasons starting from MJJ to OND (Figure 4a). It is important to note here that both the indices have maximum impression during the monsoon season as the PPMC value is highest during the MJJ season 0.71 and 0.74 respectively (Figure 4a). The PPMC value decreases from positive high to positive moderate when we move further into ASO, SON and OND seasons. DMI is strongest during the monsoon season with its moderate r= 0.40 for JJA while it is very low during the post-monsoon during winter with its r= 0.19 in OND (Figure 4a).

Indian summer monsoon rainfall (ISMR) includes months starting from June, July, August and September during which monsoonal rainfall is received [28]. The previous studies were done on looking at the relationship between the ENSO events and the ISMR unearth that these two have a negative relationship[21]. The interconnection between the ENSO and ISMR is influenced by IOD[2]. Monsoonal rainfall increases with a positive IOD where it minimizes the effect of ENSO on ISMR. As discussed earlier, there is enough corroboration related to rainfall that it has an impact on vector-borne diseases.



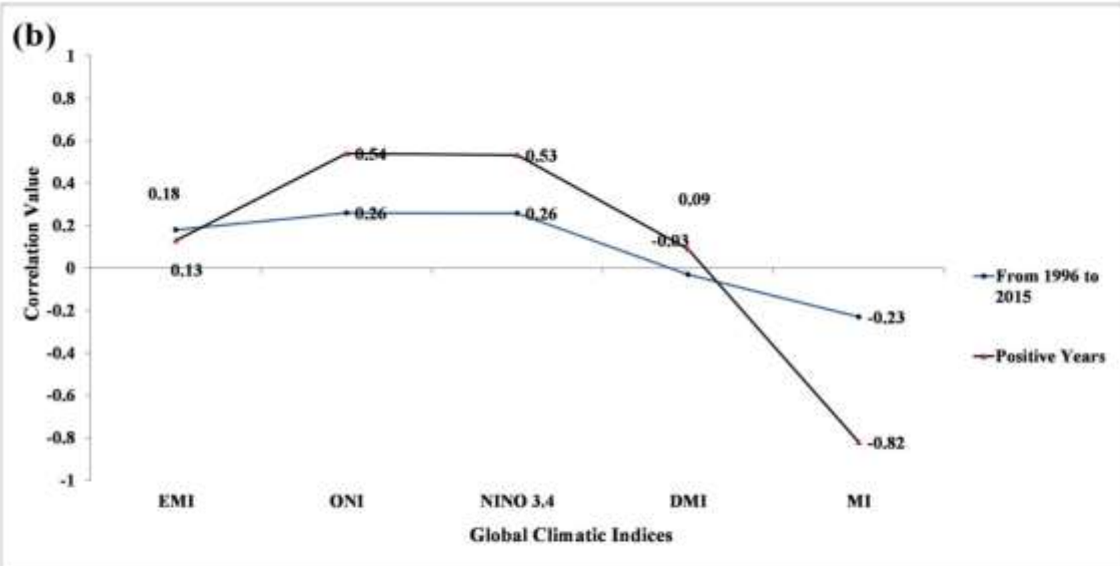


Figure 4: PPMC for global climatic factors and annually reported dengue cases (a) seasonal (MJJ, JJA, JJAS, JAS, ASO, SON, OND) PPMC during + growth years (b) PPMC for the month from May to December average value of EMI, Niño 3.4, ONI, DMI, MI (JJAS season) and number dengue cases. Blue line represents the correlation value for 20 years (1996 to 2015) while the black line is used for the + growth years

Monsoon index (MI) derived from ISMR has provided the best and significant result in connection with dengue cases with very high negative PPMC -0.82 (Figure 4a, b). It is apparent from the calculation that all the climatic indices have their impact on the dengue infection in the city but the most strong, notable and noteworthy is the ISMR.

Discussion

Previous pioneer works have suggested that climatic factors have an immense impact on the demography size, longevity, density and survival rate of Aedes mosquitoes[17-19]. The present study observed that dengue infection is moderately associated with temperature and rainy days whereas it is strongly associated with rainfall and relative humidity. The increase in temperature helps to reduce the incubation period of dengue viruses from 12 days at 30^0 C temperatures to 7 days at 32^0C- 35^0C temperature[38]. During the positive years, moderate to high positive PPMC of temperature after the monsoon season is indicating that the moderate to high temperature, absence in the rainfall and decreasing number of rainy days help in the Aedes mosquitoes population multiplication and hence an increase of infection.

During the monsoon season mainly in JJA, temperature is very high, rainfall increases which leads to a rise in relative humidity (Figure 3b). It is evident from the result that a negative relative humidity relationship can be seen during the monsoon season whereas when we move towards post-monsoon and winter season, PPMC is highly negative with a slight decrease in temperature till October and sharp falling rainfall.

Frequent and good rainfall will lead to a decrease in the density of the Aedes mosquitoes[1,34]. The most significant part of the study is the strong corroborations found between the dengue cases reported and rainfall. During the monsoon season, the disease is at its peak which is also evident from the result. The negative relationship is indicating that good rainfall will lead to washing away of larva and eggs of the mosquitoes.

During the winters when the temperature is moderate and falling, the winter rainfall with low amount provides them a positive ground for breeding. The result is indicating that low amount of rainfall during the post-monsoon season may cause an outbreak of the infection.

Our study concluded that ENSO, IOD and ISMR play an important role in influencing the number of cases. ENSO incidences are found to have a positive relationship with dengue incidences in different parts of the world[16,20,35]. The ENSO indices value in the winter months is positive during the years when + incidences were found except the year 1996. The following study also further found that ISMR increases (decreased) with the negative (positive) ENSO events. It may be possible that coupled with local climatic factors during the year 1996, DMI has a negative value in November (1995) which influences the cases in the city. In 2015 when growth is registered maximum, ENSO incidences show a very high positive value and MI incidence has a very high negative value which justifies the result that global climatic factors have a significant role in deciding the number of reported dengue cases.

Conclusion

Among several cities of north India, in Delhi particularly for the last two decades, dengue has become frequent and rampant and its ramification on the city population is of serious concern for scientists, policymakers and researchers. Study related to climatic variability and its impact on Delhi city is very limited. Several studies in a different part of the globe documented that minor climatic variation can lead to a large-scale increase in the number of cases. The limitation in this study is related to the availability of monthly dengue cases as the data is available annually. Availability of monthly data will lead to a more precise result.

The other factors including vulnerable human population, environmental and social factors also need to be present because the outbreak of infection is not presently analyzed and is a matter of future study. Among the climatic factors, monsoon index is the most significant and strong in determining the epidemiology of dengue fever. The link between ENSO and ISMR is very strong[29] based on which early forecasts of dengue cases are possible. Understanding the impact of climatic factors may help policymakers in many ways so that through proper planning and policies, the outbreak and spread of this disease can be controlled and reduced in the future.

Acknowledgement

We are thankful to National Vector Borne Disease Control Board (NVBDCB), Directorate of Economics and Statistics, Government of Delhi and Regional Metrological Department, New Delhi for providing data on dengue and monthly data on local climatic factors. We are also thankful to NOAA and JAMSTEC for proving data on different global climatic indices. ArcGIS Version 10.2 is used to draw a locational map, SPSS Version 22.0 is used to calculate the PPMC and MS Excel is used to draw the linear and bar graph.

References

1. Arcari P., Tapper N. and Pfueller S., Regional variability in relationships between climate and dengue/DHF in Indonesia, *Singapore Journal of Tropical Geography*, **28**, 251–272 **(2007)**

2. Ashok K., Behera S.K., Rao S.A., Weng H. and Yamagata T., El Niño Modoki and its possible teleconnection, *Journal of Geophysical Research*, **112**, 1-27 **(2007)**

3. Ashok K., Guan Z., Saji N.H. and Yamagata T., Individual and Combined Influences of ENSO and the Indian Ocean Dipole on the Indian Summer Monsoon, *Journal of Climate*, **17**, 3141–3155 **(2004)**

4. Banu S., Guo Y., Hu W., Dale P., Mackenzie J.S., Mengersen

K. and Tong S., Impacts of El Niño Southern Oscillation and Indian Ocean Dipole on dengue incidence in Bangladesh, *Scientific Reports*, **5(1),** 1-9 **(2015)**

5. Bezirtzoglou C., Dekas K. and Charvalos E., Climate changes, environment and infection: Facts, scenarios and growing awareness from the public health community within Europe, *Anaerobe*, **17(6),** 337–40 **(2011)**

6. Cazelles B., Chavez M., Mcmichael A.J. and Hales S., Nonstationary Influence of El Niño on the Synchronous Dengue Epidemics in Thailand, *PLoS Medicine*, **2(4),** e106 **(2005)**

7. Chakravarti A. and Kumaria R., Eco-epidemiological analysis of dengue infection during an outbreak of dengue fever, India, *Virology Journal*, **2**, 32 **(2005)**

8. Comprehensive Guidelines for Prevention and Control of Dengue and DHF, Available: http://www.bing.com/cr [accessed 13 November 2020] **(2020)**

9. Dar L., Broor S., Sengupta S. and Seth P., The First Major Outbreak of Dengue Hemorrhagic Fever in Delhi, India, *Emerging Infectious Diseases,* **5**, 589–590 **(1999)**

10. Gagnon A., Bush A. and Smoyer-Tomic K., Dengue epidemics and the El Niño Southern Oscillation, *Climate Research*, **19**, 35–43 **(2001)**

11. Githeko A.K., Lindsay S.W., Confalonieri U.E. and Patz J.A., Climate change and vector-borne diseases: a regional analysis, *Bulletin of the World Health Organization*, **78(9)**, 1136-1147 **(2000)**

12. Gubler D.J. et al, Climate Variability and Change in the United States: Potential Impacts on Vector- and Rodent-Borne Diseases, *Environmental Health Perspectives*, **109**, 223 **(2001)**

13. Guha-Sapir D. and Schimmer B., Dengue fever: new paradigms for a changing epidemiology, *Emerging Themes in Epidemiology*, **2 (1)**, 1-10 **(2005)**

14. Gupta E., Dar L., Kapoor G. and Broor S., The changing epidemiology of dengue in Delhi, India, *Virology Journal*, **3**, 92-96 **(2006)**

15. Gupta E., Dar L., Narang P., Srivastava V.K. and Broor S., Serodiagnosis of dengue during an outbreak at a tertiary care hospital in Delhi, *Indian J Med Res*, **121(1)**, 36 **(2005)**

16. Hales S., Weinstein P., Souares Y. and Woodward A., El Niño and the dynamics of vectorborne disease transmission, *Environmental Health Perspectives*, **107**, 99–102 **(1999)**

17. Hii Y.L., Rocklöv J., Ng N., Tang C.S., Pang F.Y. and Sauerborn R., Climate variability and increase in intensity and magnitude of dengue incidence in Singapore, *Global Health Action*, **2**, 2036 **(2009)**

18. Hopp M. and Foley J., Worldwide fluctuations in dengue fever cases related to climate variability, *Climate Research*, **25**, 85–94 **(2003)**

19. Huang X., Williams G., Clements A.C.A. and Hu W., Imported Dengue Cases, Weather Variation and Autochthonous Dengue Incidence in Cairns, Australia, *PLoS ONE*, **8 (12)**, 1-7 **(2013)**

20. Hurtado-Díaz M., Riojas-Rodríguez H., Rothenberg S.J., Gomez-Dantés H. and Cifuentes E., Impact of climate variability on the incidence of dengue in Mexico, *Tropical Medicine & International Health*, **12**, 1327–1337 **(2007)**

21. Ihara C., Kushnir Y., Cane M.A. and Peña V.H.D.L., Indian summer monsoon rainfall and its link with ENSO and Indian Ocean climate indices, *International Journal of Climatology,* **27**,179–187 **(2007)**

22. Johansson M.A., Dominici F. and Glass G.E., Local and Global Effects of Climate on Dengue Transmission in Puerto Rico, *PLoS Neglected Tropical Diseases,* **3**, 1-5 **(2009)**

23. Kelly-Hope L.A., Purdie D.M. and Kay B.H., Differences in Climatic Factors Between Ross River Virus Disease Outbreak and Non outbreak Years, *Journal of Medical Entomology*, **41**, 1116–1122 **(2004)**

24. Kovats R.S. and Campbell-Lendrum D.H., Early effects of climate change: do they include changes in vector-borne disease? *Philosophical transactions of the Royal Society of London*, **356(1411)**, 1057–68, **(2000)**

25. Mcmichael A.J., Global climate change: will it affect vector-borne infectious diseases?, *Internal Medicine Journal*, **33(12)**, 554–5 **(2003)**

26. Patz J.A., Martens W.J., Focks D.A. and Jetten T.H., Dengue fever epidemic potential as projected by general circulation models of global climate change, *Environmental Health Perspectives,* **106**, 147–153 **(1998)**

27. Patz J.A., Global Climate Change and Emerging Infectious Diseases, *JAMA: The Journal of the American Medical Association*, **275**, 217 **(1996)**

28. Quintero-Herrera L.L., Ramírez-Jaramillo V., Bernal-Gutiérrez S., Cárdenas-Giraldo E.V., Guerrero-Matituy E.A. and Molina-Delgado A.H., Potential impact of climatic variability on the epidemiology of dengue in Risaralda, Colombia, 2010–2011, *Journal of Infection and Public Health,* **8(3),** 291–7 **(2015)**

29. Rajeevan M., Tropical Pacific upper ocean heat content variations and Indian summer monsoon rainfall, *Geophysical Research Letters,* **31**, 1-4 **(2004)**

30. Saji N.H., Goswami B.N., Vinayachandran P.N. and Yamagata T., A dipole mode in the tropical Indian Ocean, *Nature*, **401**, 360–363 **(1999)**

31. Sharma R.S., Panigrahi N., Kaul S.M., Shivlal Barua K. and Bhardwaj M., Status report of DF/DHF during 1998 in the National Capital Territory of Delhi, India, *Dengue Bull*, **23**,109-112 **(1999)**

32. Sukri N.C. et al, Transmission of Epidemic Dengue Hemorrhagic Fever In Easternmost Indonesia, *The American Journal of Tropical Medicine and Hygiene*, **68**, 529–535 **(2003)**

33. Teixeira M.D.G., Costa M.D.C.N., Barreto M.L. and Mota E., Dengue and dengue hemorrhagic fever epidemics in Brazil: what research is needed based on trends, surveillance and control experiences?, *Cadernos de Saúde Pública*, **21**, 1307–1315 **(2005)**

34. Thammapalo S., Chongsuwiwatwong V., McNeil D. and Geater A., The climatic factors influencing the occurrence of dengue hemorrhagic fever in Thailand, *Southeast Asian J Trop Med Public Health,* **36,** 191-6 **(2005)**

35. Tipayamongkholgul M., Fang C.T., Klinchan S., Liu C.M. and King C.C., Effects of the El Niño-Southern Oscillation on dengue epidemics in Thailand, 1996-2005, *BMC Public Health*, **422,** 2-15 **(2009)**

36. Wang B. and Fan Z., Choice of South Asian Summer Monsoon Indices, *Bulletin of the American Meteorological Society*, **80**, 629–638 **(1999)**

37. Wang B., Wu R. and Lau K.M., Interannual Variability of the Asian Summer Monsoon: Contrasts between the Indian and the Western North Pacific–East Asian Monsoons, *Journal of Climate*, **14**, 4073–4090 **(2001)**

38. Watts D.M., Burke D.S., Harrison B.A., Whitmire R.E. and Nisalak A., Effect of temperature on the vector efficiency of Aedes aegypti for dengue 2 virus, *Am J Trop Med Hyg*, **36**,143–152 **(1987)**.

(Received 09th March 2021, accepted 19th May 2021)