POTENTIAL ASSOCIATION OF DENGUE HEMORRHAGIC FEVER INCIDENCE AND REMOTE SENSES LAND SURFACE TEMPERATURE, THAILAND, 1998

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Abstract. A pilot study was designed to analyze a potential association between dengue hemorrhagic fever (DHF) incidence and, temperature computed by satellite. DHF is a mosquito transmitted disease, and water vapor and humidity are known to have a positive effect on mosquito life by increasing survival time and shortening the development cycle. Among other available satellite data, Land Surface Temperature (LST) was chosen as an indicator that combined radiated earth temperature and atmospheric water vapor concentration. Monthly DHF incidence was recorded by province during the 1998 epidemic and obtained as a weekly combined report available from the National Ministry of Public Health. Conversely, LST was calculated using remotely sensed data obtained from thermal infrared sensors of NOAA satellites and computed on a provincial scale. Out of nine selected study provinces, five (58.3%) exhibited an LST with a significant positive correlation with rainfall ($p < 0.05$). In four out of nineteen surveyed provinces (21.3%), LST showed a significant positive correlation with DHF incidence ($p < 0.05$). Positive association between LST and DHF incidence was significantly correlated in 75% of the cases during non-epidemic months, while no correlation was found during epidemic months. Non-climatic factors are supposed to be at the origin of this discrepancy between seasonality in climate (LST) and DHF incidence during epidemics.

INTRODUCTION

The four dengue (DEN) virus serotypes, DEN-1 to DEN-4 (Flaviviridae: Flavivirus), are responsible of dengue fever (DF) that have a wide range for both mild and severe infections, such as dengue hemorrhagic fever (DHF). The DEN virus is transmitted by the *Aedes aegypti* mosquito, which is distributed throughout all tropical regions (Gubler, 1997).

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In 1987, the Division of Epidemiology, Ministry of Public Health in Thailand reported the highest dengue incidence, with a total morbidity rate of 325.1 cases per 100,000 population (Division of Epidemiology, 1998). During that same year, in the central plain region of Thailand, the highest dengue incidence was recorded, with a morbidity rate of 195.6 cases and a mortality rate of 0.4 cases per 100,000 population.

Dengue virus transmission depends on many environmental factors (Kuno, 1995). One of the key transmission factors is the relationship between temperature and atmospheric humidity that strongly influences vector survival duration and the efficiency of virus transmission (Hlaing *et al*, 1998). However, field studies to estimate this relation have limitations because of the point nature of climate data recording (*ie*, meteorological stations) and the difficulty of extrapolating these data over heterogeneous areas.

Remote Sensing (RS) is used as a means to depict a spatial representation of environmental factors on a larger scale, including physical as well as climatologic data (Kerr *et al*, 1998). In order to provide a better understanding of the risk factors associated with the complex epidemiology of DHF, a Geographic Information System (GIS) is a tool to combine multifactorial analysis in both spatial and temporal dimensions (Gesler, 1986).

In the present study we have compared the spatial distribution of the DHF syndrome with several environmental factors, including rainfall, air temperature, humidity, and Land Surface Temperature (LST) as climate indicators on a provincial scale in the central region of Thailand.

MATERIALS AND METHODS

Study area

The nineteen provinces of the central plains region are situated between 10º 90´ to 15º 60´ N latitude and 98º 25´ to 101º 50´ E longitude. This region includes Bangkok, Kanchanaburi, Nakhon Pathom, Ratchaburi, Suphan Buri, Chai Nat, Nakhon Pathom, Ayutthaya, Lop Buri, Samut Sakhon, Saraburi, Pathum Thani, Nakhon Nayok, Ang Thong, Samut Prakan, Samut Songkhram, Phetchaburi, Nonthaburi, Prachuap Khiri Khan, and Sing Buri provinces; with a total area of 69,520 km^2 (Fig 1).

Dengue hemorrhagic fever (DHF)

Clinically defined DHF cases (WHO, 1997) were reported on a weekly basis by hospitals to the Division of Epidemiology, Office of Permanent Secretary, Ministry of Public Health and, were provided, recorded, and computerized using a GIS format. Also, during the study period, an epidemic spread over all of Thailand in 1997-1998, which led to a national incidence two times higher than the preceding years (Division of Epidemiology, 1998).

Expected DHF (EDHF) and epidemic-month (EM)

EDHF was calculated from a retrospective analysis of dengue hemorrhagic fever incidence reports available for each province over a 16-year (1983-1998) period using a published method of calculation of the monthly incidence expected value (Barbazan *et al*, 2002). This method also allows the definition of epidemic month (EM), during which the monthly observed DHF incidence in a province is greater than the expected value plus one standard deviation.

Environmental data: National Oceanic and Atmospheric Administration (NOAA) satellite images

A ten-day composite of a NOAA-14 satellite “imagesat” that covered the period from January 21 to December 31,1998 was provided by the Asian Institute of Technology, Pathum Thani (Surat Lertlum, Personal communication).

Land Surface Temperature (LST). LST is a flux at the surface-to-atmosphere interface that can only be parameterized through the use of surface temperature. LST was calculated according to a formula developed by Kidwell (Kidwell, 1986; Kerr *et al*, 1992) and contained in the practical guides for the study of NOAA satellites images (Kidwell, 1998).

Climatic data. Climatic information, such as Relative Humidity (RH), Mean Temperature (MT), and Rainfall (RF) were obtained from the Thai Meteorological Department, Ministry of Transport and Communications (Annual Data Processing Sub-division, 2004).

Data management. The software, environment

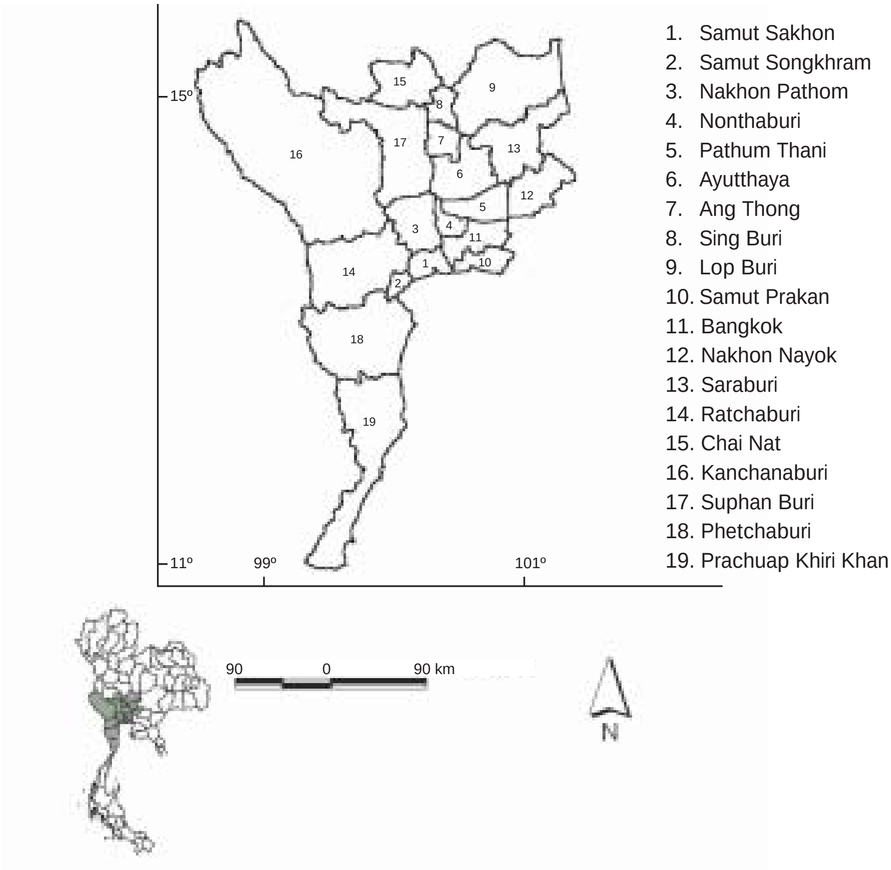

Fig 1–Central Plain of Thailand administrative boundaries.

for Visualizing Images (ENVI 3.2, 1999, Info Research Co, Ltd), was extensively used and calculations were done according to the Kidwell formula (Kidwell, 1986; Kerr *et al*, 1992) using Excel software (Microsoft Office 97).

Statistical analysis. Correlation was calculated by computing several variables within three sets of data:

1. LST versus climate: Rainfall (RF), Mean Air Temperature (MT), and Relative Humidity (RH) at a monthly scale, for the 9 provinces where 12 ground meteorological stations were located.

2. LST versus epidemiological data including DHF incidence observed in 1998 and, EDHF calculated over the 1983-1998 DHF incidence time series, for the 19 provinces.

3. LST versus incidence recorded during Epidemic Months (EM) and Non Epidemic Months (NEM), for the 19 provinces.

Correlation testing was done using the Pearson product-moment correlation coefficient calculated by SPSS version 10 (Jekel *et al,* 1996). Linear association between variables (LST and DHF incidence) was expressed as a probability value with a level of significance ($p < 0.05$).

RESULTS

Of the 19 provinces, 12 indicated an LST increase from April to September (Fig 2), and an increase of RF and RH was also observed during March to October. The Mean Temperature (MT) increased from January, to a peak in

April, and then decreased progressively until December. When we compared LST and RF, a significantly positive correlation ($p < 0.05$) appears among seven of the 12 stations in five provinces (58.3%) [including Ayutthaya (Mueang), Ratchaburi (Mueang), Lop Buri (Mueang), Kanchanaburi (Thong Pha Phum) and, Bangkok (Khlong Toei, Don Mueang Airport, and Bang Na)]. However, only Ayutthaya Province, exhibited a positive correlation between LST and RH ($p < 0.05$). No significant correlation was found between LST and MT from the ground stations (Table 1).

A positive correlation between LST and DHF was observed among four provinces (Lop Buri, Nakhon Nayok, Phetchaburi, Saraburi), and a significantly negative correlation ($p < 0.05$) was observed for Samut Sakhon Province (Table 2). Also, a positive correlation of LST and EDHF was found ($p < 0.05$) for four provinces including Ayutthaya, Nakhon Nayok, and, as above, for Phetchaburi and Saraburi.

As the 1997-1998 period was marked by an epidemic, the proportion of EM reaches 44% of the total number of months (a time series of 99 from a total of 228 months). The correlation between LST and DHF incidence during EM and NEM indicated a more robust association between LST and NEM than with EM (Tables 3-4).

DISCUSSION

Of the nineteen provinces, 58.3% showed a significantly positive correlation between LST and RF. LST depends on surface emissivity and atmospheric absorption linked to water vapor (Hay and Lennon, 1999; Hay, 2000). Water vapor increases with rainfall and produces a higher brightness (LST) in the rainy season, during May to August, when land surfaces are flooded (*eg*, rice fields) (Fig 2) (Levizzani *et al*, 1999). These months had a high value for LST but corresponded to a temperature decrease related to the rain and cloudy sky, which led to the absence of correlation between LST and air temperature.

Seasonal increase in DHF incidence is related to the rainy season, when there is filling of the breeding sites of *Aedes aegypti,* the dengue virus vector. However, only four provinces (Phetchaburi, Samut Sakhon, Lop Buri, and Nakhon Nayok) demonstrated a significantly

Table 1
Correlation coefficient (*r*) between rainfall, relative humidity, mean temperature (from station in available) and, each LST of 10 days composite satellite images, 1998.

Province/District station	Rainfall		Relative humidity		Mean temperature	
	r	p[a]	*r*	p	*r*	p
Chai Nat/Mueang	-0.13	0.480	0.24	0.179	0.15	0.399
Ayutthaya/ Mueang	0.47	0.007	0.40	0.023	0.00	0.991
Ratchaburi/ Mueang	0.44	0.012	0.05	0.939	0.16	0.381
Nakhon Pathom/Kamphaeng Saen	0.09	0.629	0.06	0.754	0.32	0.074
Suphan Buri/ Mueang	0.13	0.466	0.19	0.301	0.26	0.148
Samut Prakan/ Mueang	0.16	0.372	0.03	0.883	0.02	0.917
Lop Buri/ Mueang	0.52	0.002	0.17	0.363	-0.17	0.350
Kanchanaburi/ Mueang	0.09	0.628	0.11	0.568	0.26	0.150
Kanchanaburi/Thong Pha Phum	0.48	0.006	0.30	0.100	0.09	0.611
Bangkok/ Khlong Toei	0.51	0.003	0.24	0.181	-0.32	0.071
Bangkok/Don Mueang Airport	0.41	0.020	0.05	0.771	0.10	0.605
Bangkok/Bang Na	0.49	0.004	-0.15	0.418	-0.29	0.111
Percent significant	7/12 (58.3%)		1/12 (8.3%)		0/12 (0%)	

[a]= Probability at 95% interval

Table 2
Correlation coefficient (*r*) Expected Dengue Hemorrhagic Fever (EDHF), Dengue Hemorrhagic Fever (DHF), and Land Surface Temperature (LST) indicators in the Central Plain of Thailand, 1998.

Province	EDHF		DHF	
	r	p[a]	*r*	p
Bangkok	0.56	0.056	-0.37	0.243
Samut Sakhon	0.44	0.154	-0.63	0.028
Samut Prakan	0.54	0.072	-0.34	0.287
Samut Songkhram	0.49	0.106	-0.09	0.776
Nonthaburi	0.24	0.444	-0.20	0.532
Pathum Thani	0.39	0.205	-0.34	0.285
Nakhon Pathom	0.40	0.198	-0.13	0.687
Ratchaburi	0.40	0.202	-0.01	0.969
Kanchanaburi	0.35	0.271	0.002	0.995
Phetchaburi	0.76	0.004	0.59	0.045
Prachuap Khiri Khan	0.36	0.255	0.10	0.759
Suphan Buri	-0.01	0.980	-0.10	0.749
Sing Buri	-0.01	0.976	0.46	0.134
Ayutthaya	0.76	0.004	-0.04	0.914
Saraburi	0.62	0.031	0.81	0.001
Lop Buri	0.45	0.143	0.69	0.014
Chai Nat	0.15	0.641	0.20	0.537
Ang Thong	-0.06	0.986	0.43	0.162
Nakhon Nayok	0.75	0.005	0.65	0.021
Percent significant[b]	4/19 (21%)		4/19 (21%)	

[a]= Probability at 95% interval
[b]= Significant positive correlation ($p<0.05$)/total tested

Table 3
Correlation (*r*) of Land Surface Temperature (LST) with Dengue Hemorrhagic Fever (DHF) incidence among epidemic (EM) and non-epidemic months (NEM) of the 19 provinces of the Central Plain of Thailand in 1998.

Description	LST[a]	
	EM (*r*)	NEM (*r*)
DHF[b]	0.13	0.68
DHF incidence[c]	0.08	0.74

[a]LST of epidemic month (EM) and non epidemic month (NEM)
[b]Number of cases
[c]Case rate reported to 100,000 inhabitants

positive correlation ($p < 0.005$) between LST and monthly DHF incidence; most of the provinces exhibited a negative trend (not significant), whereas Samut Sakhon Province presented a negative correlation between DHF and LST. However, the EDHF followed generally the same seasonal pattern than the LST, increasing from May to September, during the rainy season. Positive correlation with EDHF was generally higher than with the observed values (Table 2).

However, a comparison between LST and DHF incidence, when epidemic and non epidemic months are studied separately, shows a highly significant correlation with the non epidemic months ($p < 0.05$). A possible interpretation is that, during the 1997-1998 epi-

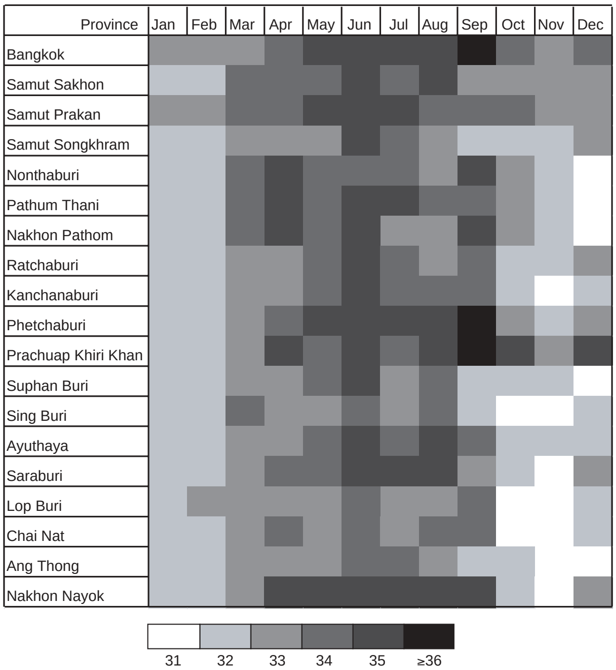

Fig 2–Land Surface Temperature (ºC) of the Central Plain of Thailand, 1998.

demic, non-climatic factors, such as herd immunity, virus transportation, or distribution of the different serotypes were causes of the monthly increases in incidence, to a level significantly higher than the EDHF values (Kuno, 1995). The EDHF, being calculated during periods of normal (*eg*, non-epidemic) incidence, and the relation with the climate being stable, therefore, the outbreak would create a divergence between climate indicators (LST) and the observed values of incidence. Altogether, DHF/EDHF appeared to correlate with LST when a province was in an endemic situation.

In conclusion, the present findings would recommend further study on the use of the computation of satellite imaging during inter-epidemic

Table 4
Distribution of Dengue Hemorrhagic Fever (DHF) epidemic months (value= 0) and non epidemic months (value = 1) calculated for the 19 study provinces.

No	Province	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Bangkok	0	0	0	0	0	0	0	0	0	0	0	0
2	Samut Sakhon	0	0	0	0	0	0	1	1	1	1	1	1
3	Samut Prakan	0	0	0	0	0	0	0	0	0	0	0	0
4	Samut Songkhram	0	0	0	0	0	1	1	1	1	1	1	1
5	Nonthaburi	0	0	0	0	0	0	0	0	0	0	0	0
6	Pathum Thani	0	0	0	0	0	0	1	1	1	1	1	1
7	Nakhon Pathom	0	0	0	0	0	0	0	1	1	1	0	0
8	Ratchaburi	0	0	0	0	1	1	1	1	1	1	1	1
9	Kanchanaburi	0	0	0	0	1	1	1	1	1	1	1	1
10	Phetchaburi	0	0	0	0	0	0	0	0	0	1	1	1
11	Prachuap Khiri Khan	0	0	0	0	0	0	0	1	1	1	1	1
12	Suphan Buri	0	0	0	0	0	1	1	1	1	1	1	1
13	Sing Buri	0	0	0	0	0	0	0	0	1	1	1	1
14	Ayutthaya	0	0	0	0	0	0	0	1	1	1	1	1
15	Saraburi	0	0	0	0	0	0	0	0	1	1	1	1
16	Lop Buri	0	0	0	0	0	0	0	0	1	1	1	1
17	Chai Nat	0	0	0	0	0	1	1	1	1	1	1	1
18	Ang Thong	0	0	0	0	1	1	1	1	1	1	1	1
19	Nakhon Nayok	0	0	0	0	0	0	0	0	1	1	1	1

phases at the provincial level as a potential climate dependent indicator. The observed discrepancy between DHF transmission and seasonal variations could help to establish an early warning system.

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