Using Seasonal Forecast Data to Predict the Occurrence of Dengue Fever

WEI-TEH LI

Atmospheric Science Program, Department of Geological and Atmospheric Sciences, Iowa State University, Ames, Iowa

1 May 2002

1. Introduction

Dengue fever (DF) is one of the most important mosquito-borne viral diseases of humans and transmitted to humans through the bites of infected female Aedes aegypti mosquitoes. There has been a dramatic increase in geographic spread, numbers of cases and severity of disease in the past 30 years. Currently 2.5 billion of the world populations, primarily in tropical developing countries, are at risk; distributions of dengue fever are shown in figure (1). Annually, there are estimated to be tens of millions of cases of the disease. Hundreds of thousands of these are of the more severe dengue hemorrhagic fever (DHF) that is a leading cause of childhood hospitalization and death in many countries.
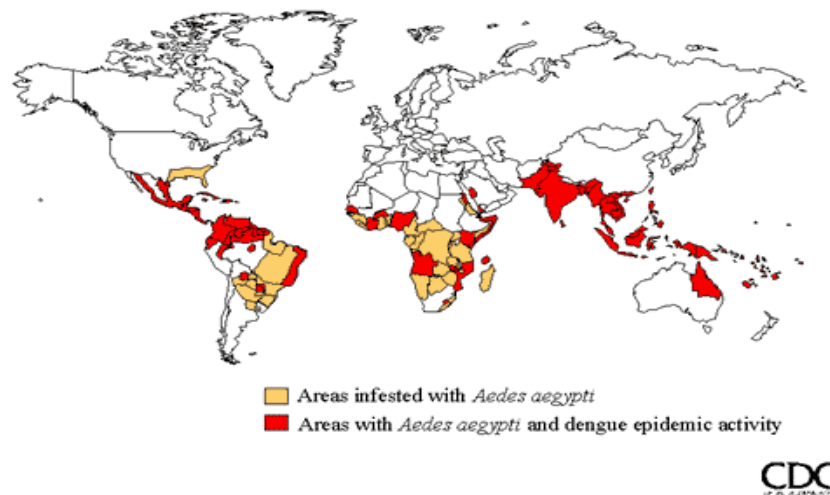

Figure (1) The general distribution of dengue fever in 2000; nowadays, the most occurrences are still distributed in those shaded areas. (From Centers for Disease Control and Prevention)

In recent years, dengue fever (DF) has become a major international health problem affecting tropical and sub-tropical regions around the world - especially in urban and peri-urban areas. The geographic distribution of dengue fever, the frequency of epidemic cycles, and the number of cases of dengue have increased sharply during the last two decades.

Dengue fever is a severe flu-like illness that affects infants, young children and adults, but rarely causes death. Symptoms vary according to age. Infants and young children may be asymptomatic or have undifferentiated fever and rash, whereas older children or adults are more likely to have a more severe set of symptoms including high fever that starts quickly, sometimes with two peaks, and/or severe headache, pain

behind the eyes, muscle and joint pains, nausea and vomiting and rash.

As mentioned, dengue viruses are transmitted to humans through the bites of infective female Aedes aegypti mosquitoes. Mosquitoes acquire the virus while feeding on the blood of an infected person. Once infected, a mosquito is capable of transmitting the virus to susceptible individuals for the rest of its life, during probing and blood feeding. Infected female mosquitoes may also transmit the virus to the next generation of mosquitoes by transovarial transmission (i.e. via its eggs), but the role of this in sustaining transmission of virus to humans has not yet been delineated. Humans are the main amplifying host of the virus, although we've known that in some parts of the world monkeys may become infected and perhaps serve as a source of virus for uninfected mosquitoes. The virus circulates in the blood of infected humans for 2-7 days, at approximately the same time as they have fever; Aedes mosquitoes may acquire the virus when they feed on an individual at this time.

In this study, I'd like to find a relationship between the forecasting data (such as temperature and precipitation) and the statistical data of dengue fever. Then, the relationship could be helpful to predict the occurrences of dengue fever and to provide the health organizations a possible duration and location to prevent or control the disease in advance.

2.   Data

The statistical data of dengue fever are separately from the websites of World Health Organization (WHO) and Department of Health in Taiwan, R.O.C. (DOH).

WHO provides the global statistical data, including possible and confirmed cases in more than 80 different countries among forty-four years (i.e. from 1955 to 1998), lots of general information and facts about dengue fever and the ways to prevent and control.

DOH especially makes a table of occurrences of dengue fever for the area of Taiwan and a comparison of that in different countries in Southeast Asia. Besides, websites of Centers for Disease Control and Prevention (CDC) and National Oceanic and Atmospheric Administration (NOAA) also provide lots of general facts and interesting statistical data.

3.   Methods

In general, dengue fever occurs almost in the area of tropical and part of subtropical areas over the world. In Southeast Asia, middle Africa, middle or South America and part of Northeast Australia, people could have chance to be infected during the summer time.

Because not every country has disease data in detail for each year, and some countries have even much missing data, here I select one or two countries of large cases in two main areas to discuss. They are Vietnam for the Southeast Asia and Venezuela and Colombia for the South America, and these data are in ten years from 1989 to 1998.

Table of N_C(DF)

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
SE Asia	40205	37569	111817	51311	53674	44944	80447	89963	108000	150898
S America	14117	28351	21662	22837	34644	42931	83339	42335	48612	81441

Here it is assumed that the occurrence of dengue fever is related to the amount of Aedes aegypti. And the amount of mosquitoes has a correlation with their life cycle.

Based upon this point, the disease data starts from April and end in September, so the lead-time is six months and in average the peak occurrence of dengue fever is in August and September in the Asian area and in April and May in the American area. Therefore, the red squares in figure (2) show the average disease case numbers from April to September (unit = 10,000 cases).

Table of DF in percentage (%)

Months	Apr.	May.	Jun.	Jul.	Aug.	Sep.
SE Asia	15.08	16.08	16.58	17.09	17.58	17.59
S America	17.60	17.58	16.75	16.54	15.76	15.77

In order to compare with the statistical data of dengue fever, I use monthly outputs of temperature and precipitation from the model among twenty-one years (from 1979 to 1999). Both of the data are on a grid of 1.875 degrees of either latitude or longitude. Four grid points are selected for each previously mentioned areas (i.e. Southeast Asia and South America). By averaging the monthly model output data in first ten years (from 1979 to 1988), I have a set of climatological data for each area. This is to test how the average disease case numbers (red squares) go with temperature and precipitation data. It seems that the occurrence line has a tendency as the precipitation line. Then, averaging the rest of monthly model outputs (from 1989 to 1999) and comparing with the occurrence lines, if it works, I'd average the output data for twenty-one years and compare them with the tendency of disease data.

In figure (2), the green triangles represent temperature (T, unit = K) and blue circles represent precipitation (P, unit = mm/day). Then, plug the temperature and precipitation data into my index function (as below) to compute the monthly index.

Table of the weighting factors

Months	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Temperature	6	6	6	4	2	2
Precipitation	10	10	8	8	6	6

INDEX = **SUM** (weightings)(errors)
= $6\mathbf{T}$(Apr)+$6\mathbf{T}$(May)+$6\mathbf{T}$(Jun)+$4\mathbf{T}$(Jul)+$2\mathbf{T}$(Aug)+$2\mathbf{T}$(Sep)
   +$10\mathbf{P}$(Apr)+$10\mathbf{P}$(May)+$8\mathbf{P}$(Jun)+$8\mathbf{P}$(Jul)+$6\mathbf{P}$(Aug)+$6\mathbf{P}$(Sep)

The index results could form an annual tendency for the occurrence of dengue fever after comparing with the yearly disease data.

4. Discussion
a. The relation between dengue fever and temperature
From figure (2), the occurrence of dengue fever is not quite related to the temperature. Although the temperatures are almost the same in both areas, the tendencies of occurrences are different. In Southeast Asia, peak temperature is in April and goes down with time, but the occurrence is a little small in the beginning month, increases with time and the peak occurrence concentrates in August and September. In South America, the temperature is higher either in the beginning or the ending months (i.e. April and September), and lower in the middle of the summer period, but the peak occurrence of dengue fever is in Aril and decreases with time.

Therefore, it seems that temperature has no direct relation with the occurrence of dengue fever.
b. The relation between dengue fever and precipitation
On the other hand, the precipitation does really have something to do with the occurrence of dengue fever. In Southeast Asia, precipitation tends to increase from

April and has a peak amount around August and September. During the summer time in this area, it is the famous monsoon season and large amount of water vapor from ITCZ (Inter-Tropical Convergence Zone) would be transported to Southeast Asia by the prevailing southwest or south wind and then form a lot of precipitation here. Also, South America is located pretty close to ITCZ that could provide large amount of water vapor directly, thus, there is a lot of precipitation here. Of course, such a humid environment could help mosquitoes to find a better place to grow, and it is obvious that the occurrence line and the precipitation line look quite the same with each other.

From the above, precipitation plays a much important role, however, I still need temperature to modify the index.

c. More discussion

Originally, I assume that the occurrence of dengue fever would grow with the amount of Aedes aegypti mosquitoes, because this is a kind of mosquito-borne viral disease. And the life cycle of those mosquitoes becomes an important point to consider when the life cycle is, how the mosquitoes grow and under what kind of environment they'd like to live. The fact is, only higher temperature or only humid area can't be the only one advantage for them to live.

After the previous discussion in *a* and *b*, and comparing with the statistical disease data and the hindcasting data, I get a rough approximation which could correlate all the data together, that is

$$N_C(DF) \quad C_T * T(month) + C_P * P(month)$$

where $C_T = 0.047878$ and $C_P = 0.160873$

Following the formula and plug in the forecasting data of temperature and precipitation, now in figure (3), the forecasting case number of dengue fever $N_C(DF)$ (green squares) shows that the peak occurrence will be in August in the Southeast Asia and in April in the South America.

5.   Conclusion

Annually, dengue fever prevails usually during the summer period in the areas of tropics and subtropics. Especially, those children under the age of six years are in a high dangerous group to be infected and even die of this disease. Some adults could also have a chance to be infected.

In this study, I use monthly mean data of temperature and precipitation for twenty-one years to compare with the statistical data of dengue fever for ten years and find out a relation among these data. Hopefully, the process and final index could be a little helpful to predict and control the occurrence of dengue fever. The future study could focus on improving the index for different areas or use all the predicting disease indices to form a global predicting net for dengue fever.

6.   Reference

Centers for Disease Control and Prevention website: http://www.cdc.gov/

Department of Heath, Taiwan, R.O.C. website: http://www.doh.gov.tw/
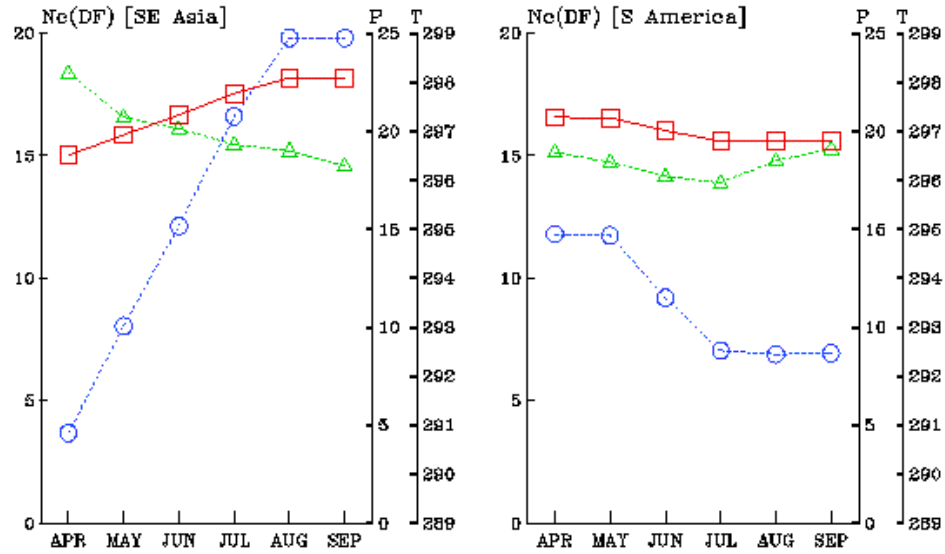
Luft, Patrick, 1996: Mosquitoes and Dengue.

Mai, Chiang, 2000: Declaration on dengue/dengue hemorrhagic fever, November 24, 2000.

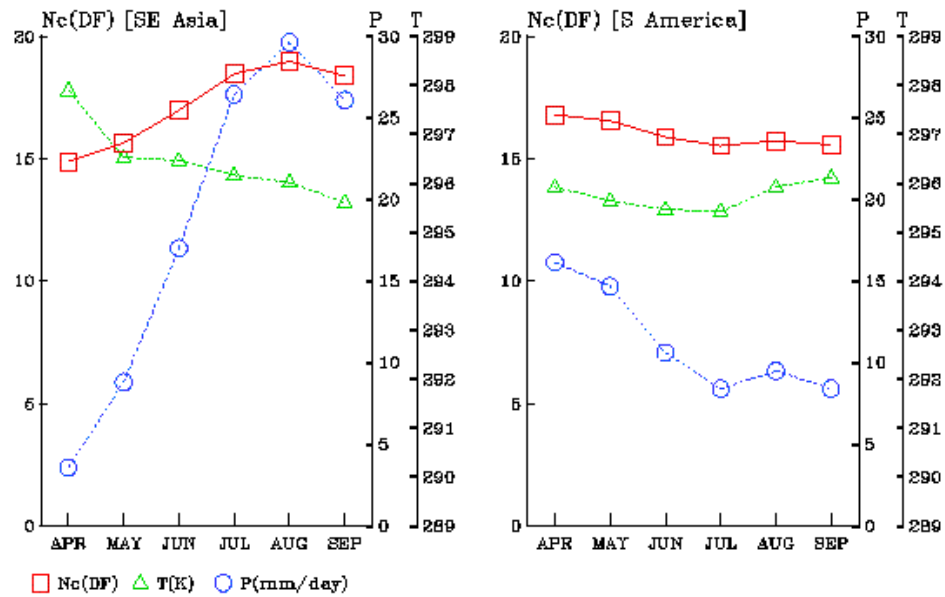National Oceanic and Atmospheric Administration website: http://www.noaa.gov/

Spira, Alan, 1998: Dengue fever, February 13, 1998.

World Health Organization website: http://www.who.org/

(2) Nc(DF) vs Hindcast(1979/1999)

(3) Nc(DF) vs Forecast(2002)

Nc(DF) △ T(K) ○ P(mm/day)

(end of figures)