

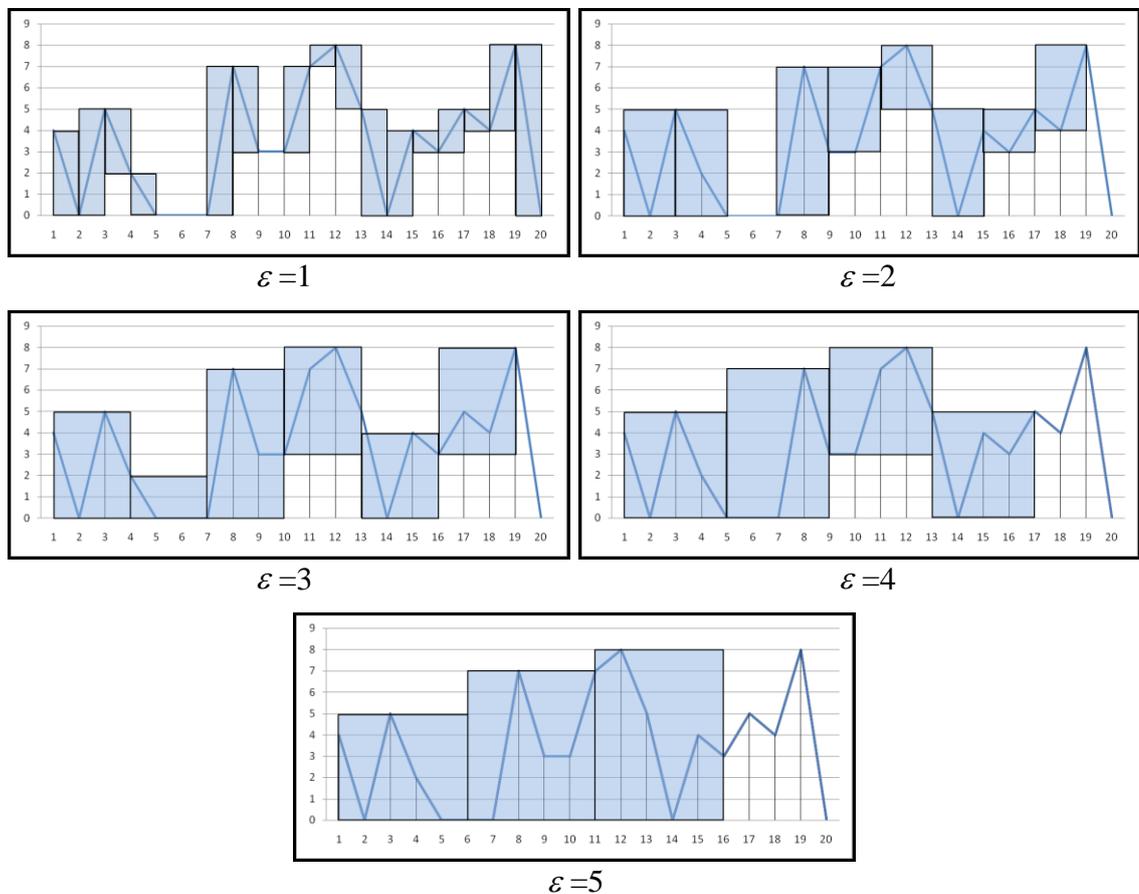
## CHAPTER 3 METHODOLOGY

Before computing fractal dimension by the variation method, a problem with the variation method is investigated. In this study, an improved variation method is proposed. The proposed method is then used in finding the fractal dimensions of wind speed and wind direction of Southeast Asian summer monsoon in time series data. The time series data from wind stations in Thailand and from the National Center for Environmental Prediction (NCEP) are used in this study. The values of the calculated fractal dimension are determined and verified.

### 3.1 A Problem of the Variation Method

In the variation method (VM), the values of areas that cover the time series curve are used for calculating the fractal dimension of the time series. The area that covers the time series curve is calculated from upper and lower boundaries of the curve and the corresponding horizontal distance. The value of area can be found from the height and length of the curve. The difference between the maximum and the minimum values of the curve are used as the height. Distances between two data points are used as the length.

However, there are some intervals of the curve that are covered by excessive areas, as shown in Figure 3.1.



**Figure 3.1** Excessive areas that cover the curve with various values of  $\epsilon$ .

In Figure 3.1, for all values of  $\varepsilon$  except for  $\varepsilon=1$  there are excessive areas that cover the curve.

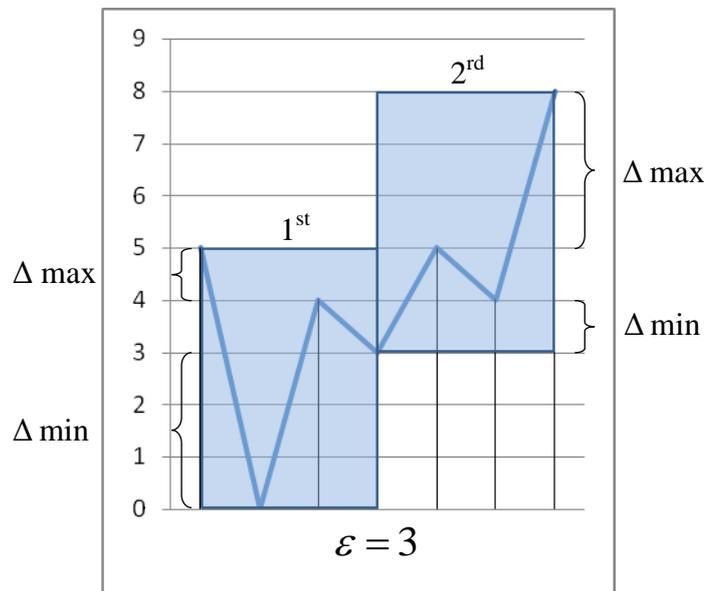
### 3.2 Improved Variation Method

A method to improve the accuracy of fractal dimension estimation by the variation method is proposed here and it is called Improved Variation Method (IVM). This method which can decrease the excessive area, comprises of 2 steps as follows.

1. Determine the extreme to be modified.
2. Specify the new extreme.

#### 3.2.1 Determine the Extreme to be Modified

This is done by finding the differences between the two largest maxima and the two smallest minima. If the difference of the maxima is less than the difference of the minima, the new maximum will be determined. Otherwise, the new minimum will be determined instead. This is illustrated in Figure 3.2.



**Figure 3.2** Example of the differences of the minima and the maxima.

From Figure 3.2, the differences between the minima ( $\Delta \min$ ) and the maxima ( $\Delta \max$ ) in the 2<sup>nd</sup> cover can be calculated from

$$\begin{aligned} \Delta \max &= |\max_1 - \max_2| \\ &= |8 - 5| = 3 \end{aligned} \quad (3.1)$$

$$\begin{aligned} \Delta \min &= |\min_1 - \min_2| \\ &= |4 - 3| = 1 \end{aligned} \quad (3.2)$$

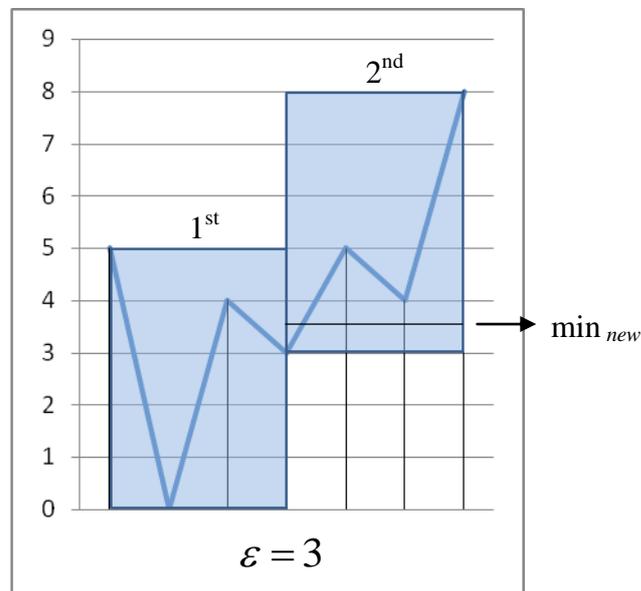
From Equations (3.1) and (3.2), the difference of the minima is less than that of the maxima. Thus, the new minimum will be determined.

For the case when the difference of maxima equals the difference of minima either the maximum or the minimum can be selected.

### 3.2.2 Specify the New Extreme

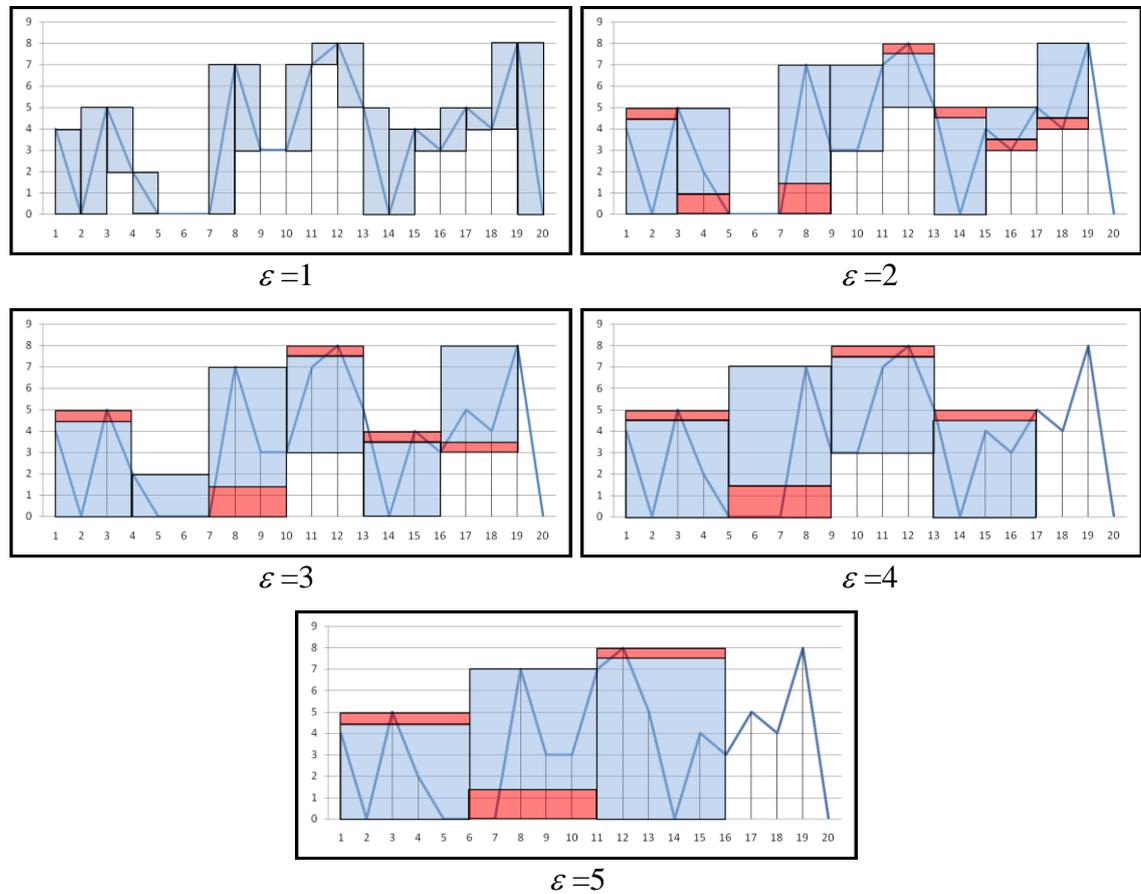
After the maximum/minimum has been determined for modification, the next step is to specify the new maximum/minimum. The new extreme is specified from averaging of the corresponding two largest/smallest of maxima/minima. An example of this process is shown in Figure 3.3 using the example in Section 3.2.1. From Figure 3.2, the difference of the minima ( $\Delta\min$ ) for the 2<sup>nd</sup> cover is smaller than the difference of the maxima ( $\Delta\max$ ). Thus, the new minimum ( $\min_{new}$ ) for the 2<sup>nd</sup> cover is obtained from the equation

$$\begin{aligned}\min_{new} &= \frac{\min_1 + \min_2}{2} \\ &= \frac{4 + 3}{2} = 3.5\end{aligned}\quad (3.3)$$



**Figure 3.3** Example of determination of the new minimum.

The IVM can reduce the excessive areas as shown in Figure 3.4. The areas with red color are the excessive areas that have been removed



**Figure 3.4** Decreasing the excessive areas.

### 3.3 Study Location

The time series data of wind speeds and wind directions at 5 meteorological centers over Thailand during summer monsoon are used for this research. These 5 meteorological centers are located in northern, northeastern, southern (west coast), southern (east coast) and central Thailand, as shown in Figure 3.5.



**Figure 3.5** Five wind stations (●) used in this study (Nations Online project,2013).

#### Chiang Mai Airport Wind Station (CM)

Chiang Mai Airport wind station is in the northern part of Thailand, located at latitude and longitude  $18.47^{\circ}\text{N}$  and  $98.59^{\circ}\text{E}$ , respectively. Geography of this station is mostly high mountains and far from the sea.

#### Ubon Ratchathani Wind Station (UR)

Ubon Ratchathani wind station is in the northeastern part of Thailand, located at latitude and longitude  $15.15^{\circ}\text{N}$  and  $104.52^{\circ}\text{E}$ , respectively. This area is mostly plateau.

#### Phuket Airport Wind Station (PK)

This location is over the Andaman Sea, located at latitude and longitude  $7.53^{\circ}\text{N}$  and  $98.24^{\circ}\text{E}$ , respectively. Phuket Airport wind station is in an island in the southern (west coast) part of Thailand.

#### Songkhla Wind Station (SK)

This station is in the southern (east coast) part of Thailand, located at latitude and longitude  $7.11^{\circ}\text{N}$  and  $100.37^{\circ}\text{E}$ , respectively. The station is close to the Gulf of Thailand.

#### Bangkok Wind Station (BK)

This station is in the central region of Thailand, located at latitude and longitude  $13.44^{\circ}\text{N}$  and  $100.34^{\circ}\text{E}$ , respectively. Bangkok wind station is over low land.

### 3.4 Data

Two sets of data are used in this study. The first set is 3-hourly surface wind observation from the 5 meteorological centers mentioned in Section 3.3. The locations of these 5 meteorological centers are shown in Table 3.1. These stations have different climatic conditions. Surface (10m) wind speeds and wind direction in summer (mid-May to mid-October) during the years 2003 to 2012 are used. The second set is 850 hPa wind from National Center for Environmental Prediction (NCEP). These data are on  $1.0 \times 1.0$  degree grid, available for every six hours. The grid points that are nearest to the five meteorological centers are used to represent the 850 hPa wind at the corresponding centers, as shown in Table 3.2.

**Table 3.1** The locations of meteorological centers used for surface wind.

Case	Province	Station	N	E
1	Chiang Mai	Chiang Mai Airport	18.47	98.59
2	Ubon Ratchathani	Ubon Ratchathani	15.15	104.52
3	Phuket	Phuket Airport	7.53	98.24
4	Songkhla	Songkhla	7.11	100.37
5	Bangkok	Bangkok	13.44	100.34

**Table 3.2** The locations for 850 hPa wind.

Station	N	E
Chiang Mai Airport	18	99
Ubon Ratchathani	15	105
Phuket Airport	8	98
Songkhla	7	100
Bangkok	13	100

### 3.5 Fractal Dimension Calculation

Fractal dimensions of summer monsoon wind at the study locations are calculated by the improved variation method (IVM) in Section 3.2. The steps to calculate the fractal dimension by IVM can be summarized as follows.

**Step 1:** Plot the observed wind speed/direction data as time series.

**Step 2:** Define the selected period of time as the interval  $[0, 1]$ .

**Step 3:** Divide the interval  $[0, 1]$  into  $N_i$  subintervals.

**Step 4:** Define the length of the subinterval as  $\varepsilon_i = (1/N_i)$ .

**Step 5:** Define the new maximum or minimum as explained in Section 3.2.

**Step 6:** Calculate the height of the area covered by the time series curve of each  $n$  from Eq. (2.16)

$$v_i(x, \varepsilon) = \max f(x_i) - \min f(x_i), |x_i - x| < \varepsilon$$

**Step 7:** Calculate the total area that is covered by the time series curve from

$$V(\varepsilon) = \frac{1}{N+1} \sum_{i=1}^N v(x, \varepsilon) \quad (3.4)$$

**Step 8:** Substitute the values obtained from Step 4 and Step 7 in  $\log(V(\varepsilon)/\varepsilon^2)$  and  $\log(1/\varepsilon)$ , respectively.

**Step 9:** Repeat Step 5 to Step 9 for smaller  $\varepsilon$ , ( $\varepsilon_i > \varepsilon_{i+1}$ ), for several values.

**Step 10:** The fractal dimension is the slope of a log-log plot of  $V(\varepsilon)/\varepsilon^2$  vs.  $(1/\varepsilon)$ .

### 3.6 Experiments

Fractal dimensions of 10-year and yearly (2003 to 2012) surface and 850 hPa wind speeds and wind directions at the five wind stations during summer monsoon over Thailand are calculated. The experiment cases are shown in Table 3.3.

**Table 3.3** Experiment cases.

Case		Location	Interval	Level
1	A	Chiang Mai	10-Year	Surface
	B	Chiang Mai	10-Year	850 hPa
	C	Chiang Mai	Yearly	Surface
	D	Chiang Mai	Yearly	850 hPa
2	A	Ubon Ratchathani	10-Year	Surface
	B	Ubon Ratchathani	10-Year	850 hPa
	C	Ubon Ratchathani	Yearly	Surface
	D	Ubon Ratchathani	Yearly	850 hPa
3	A	Phuket	10-Year	Surface
	B	Phuket	10-Year	850 hPa
	C	Phuket	Yearly	Surface
	D	Phuket	Yearly	850 hPa
4	A	Songkhla	10-Year	Surface
	B	Songkhla	10-Year	850 hPa
	C	Songkhla	Yearly	Surface
	D	Songkhla	Yearly	850 hPa
5	A	Bangkok	10-Year	Surface
	B	Bangkok	10-Year	850 hPa
	C	Bangkok	Yearly	Surface
	D	Bangkok	Yearly	850 hPa

In addition, each experiment case is further divided into 3 sets; 6-hourly and daily

