

## CHAPTER 4 RESULTS AND DISCUSSION

### 4.1 Comparison between VM and IVM

From fractal dimension calculation of wind data explained in Chapter 3, fractal dimensions of 10-year and yearly surface and 850 hPa winds are calculated by VM and IVM. For example, fractal dimensions of 6-hourly surface wind direction at Bangkok by these methods are shown in Table 4.1. Both methods have similar values but IVM fractal dimension is slightly more than VM fractal dimension. This is because IVM reduces the excessive area which results in higher accuracy in the approximation of fractal dimension.

**Table 4.1** Examples of fractal dimensions of 6-hourly surface wind direction at Bangkok.

Year	VM	IVM
2003	1.289	1.297
2004	1.280	1.290
2005	1.298	1.303
2006	1.279	1.288
2007	1.289	1.297
2008	1.300	1.304
2009	1.288	1.290
2010	1.278	1.280
2011	1.259	1.263
2012	1.285	1.288

### 4.2 Fractal Dimension of 10-year Summer Monsoon Wind

Fractal dimensions of 10-year (2003 to 2012) surface wind speed and direction from the 5 meteorological centers and 850 hPa wind from NCEP during summer monsoon over Thailand are calculated. The data are divided in to three sets namely, 6-hourly, daily maximum and daily minimum data. In Section 4.2.1, the fractal dimensions by IVM for Chiang Mai (CM), Ubon Ratchathani (UB), Phuket (PK), Songkhla (SK) and Bangkok (BK) are shown. Results for NCEP data are shown in Section 4.2.2.

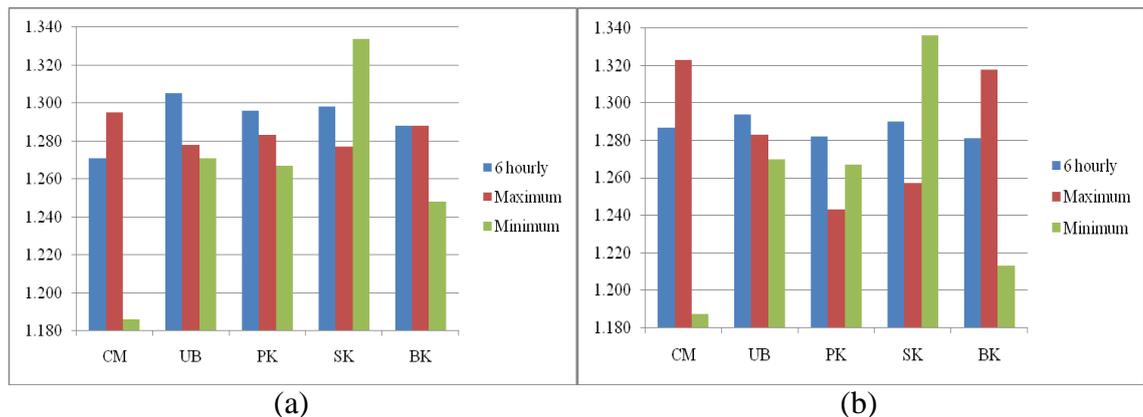
#### 4.2.1 Fractal Dimension of Surface Wind (Case A)

From Tables 4.2, 4.3 and Figure 4.1a, the 6-hourly, daily maximum and daily minimum surface wind speeds of Ubon Ratchathani and Phuket have similar pattern of fractal dimension in terms of relative magnitudes of the fractal dimensions.

The fractal dimension for daily minimum wind speed of Chiang Mai is much lower than the other stations. That is Chiang Mai has the smallest fluctuation in the minimum surface wind speed. Table 4.2 and Figure 4.1a show that the fractal dimension of daily minimum surface wind speed is less than fractal dimensions of 6-hourly and daily maximum wind speed for all stations except Songkhla. While the fractal dimension of 6-hourly wind speed is larger than those of maximum and minimum at Ubon Ratchathani and Phuket. The fractal dimension of daily maximum wind speed is larger than those of 6-hourly and minimum only at Chiang Mai.

**Table 4.2** Fractal dimensions of 6 hourly, daily maximum and daily minimum for surface wind speed and wind direction.

Province	Fractal Dimension					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
CM	1.271	1.295	1.186	1.287	1.323	1.187
UB	1.305	1.278	1.271	1.294	1.283	1.270
PK	1.296	1.283	1.267	1.282	1.243	1.267
SK	1.298	1.277	1.334	1.290	1.257	1.336
BK	1.288	1.288	1.248	1.281	1.318	1.213



**Figure 4.1** Fractal dimensions of 6-hourly, daily maximum and daily minimum for surface wind speed (a) and wind direction (b).

From Table 4.2 and Figure 4.1b, 6-hourly, daily maximum and daily minimum surface wind directions for each station has different pattern of fractal dimension. The fractal dimension for the daily minimum surface wind direction at Chiang Mai is very low. Thus, Chiang Mai has the smallest fluctuation in daily minimum surface wind direction.

The relative magnitudes of fractal dimensions for surface wind speed and direction are the same for CM, UB and SK. While the relative magnitudes of fractal dimensions for surface wind speed and direction for PK and BK are different.

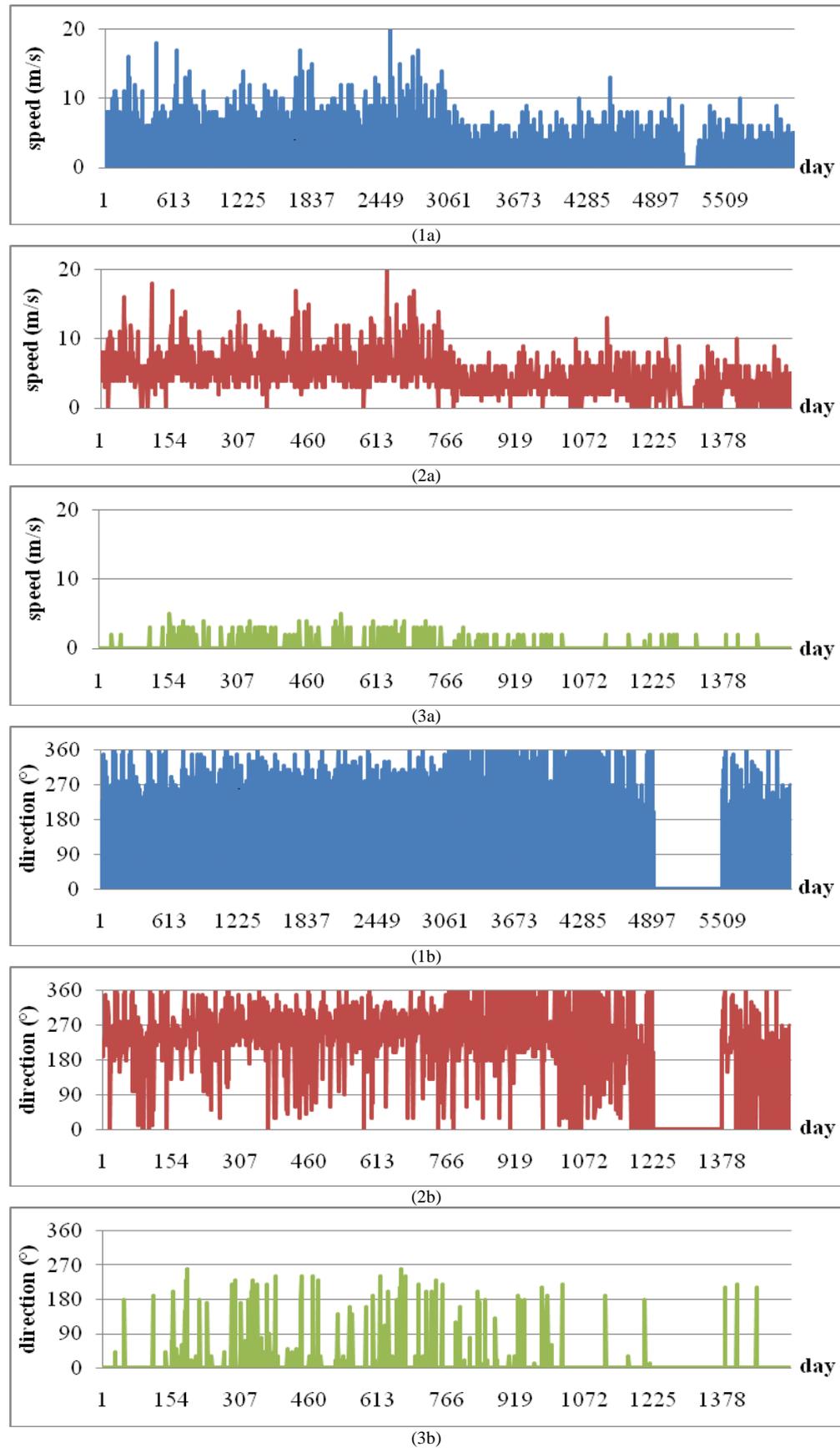
From Table 4.2 and Figure 4.1, CM has the lowest fractal dimensions for both speed and direction. Figure 4.2 shows that the time series of wind speed and direction at CM for daily minimum have the smallest variations when compare with those of 6-hourly and daily maximum wind speeds and directions. The reason could be that CM is located in a valley so that minimum wind speed and direction have less variation.

The highest and lowest fractal dimensions for wind speed and direction are shown in Table 4.3. Different colors are used for easy identification of each province.

**Table 4.3** Fractal dimensions of surface wind.

10-year	Speed		Direction	
	Highest	Lowest	Highest	Lowest
6-hourly	1.305 UB	1.271 CM	1.294 UB	1.281 BK
Daily Max	1.295 CM	1.277 SK	1.323 CM	1.243 PK
Daily Min	1.334 SK	1.186 CM	1.336 SK	1.187 CM

From this table, Ubon Ratchathani has the highest fractal dimensions for both wind speed and direction for 6-hourly data. Chiang Mai has the highest fractal dimensions for both wind speed and direction for daily maximum data, while Songkhla has the highest fractal dimensions for both wind speed and direction for daily minimum data. For the lowest fractal dimensions, Chiang Mai has the lowest values for both wind speed and direction for daily minimum data.



**Figure 4.2** Time series of 6-hourly (1), daily maximum (2) and daily minimum (3) surface wind speed (a) and wind direction (b) at Chiang Mai during the 10-year study period.

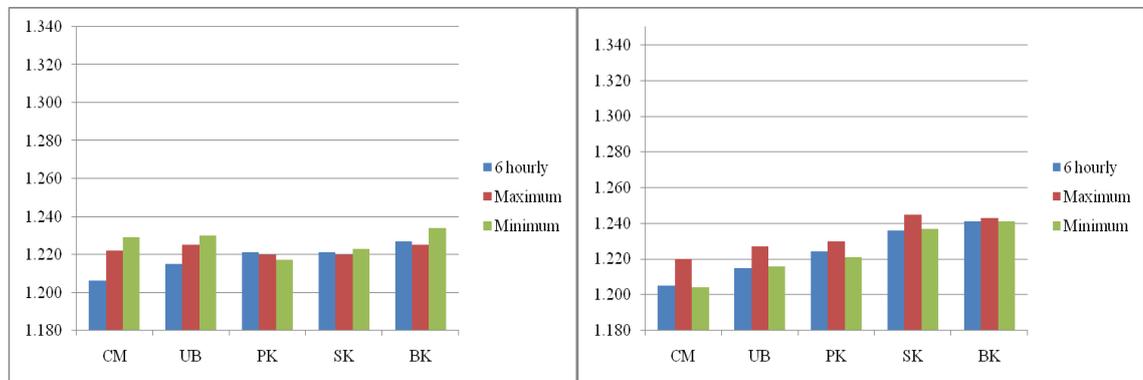
### 4.2.2 Fractal Dimension of 850 hPa Wind (Case B)

From Table 4.4 and Figure 4.3a, the 6-hourly, daily maximum and daily minimum 850 hPa wind speeds of Phuket and Songkhla have close values of fractal dimension.

The fractal dimension for 6-hourly wind speed of Chiang Mai is the lowest among all stations. That is Chiang Mai has the smallest fluctuation in the minimum 850 hPa wind speed. Table 4.4 and Figure 4.3a show that at 850 hPa, fractal dimension of daily minimum wind speed is higher than fractal dimensions of 6-hourly and daily maximum wind speed for all stations except Phuket. The fractal dimension of 6-hourly wind speed is smallest at Chiang Mai. The fractal dimension of daily maximum wind speed is largest at Ubon Ratchathani and Bangkok.

**Table 4.4** Fractal dimensions of 6-hourly, daily maximum and daily minimum for 850 hPa wind speed and wind direction.

Province	Fractal Dimension					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
CM	1.206	1.222	1.229	1.205	1.220	1.204
UB	1.215	1.225	1.230	1.215	1.227	1.216
PK	1.221	1.220	1.217	1.224	1.230	1.221
SK	1.221	1.220	1.223	1.236	1.245	1.237
BK	1.227	1.225	1.234	1.241	1.243	1.241



**Figure 4.3** Fractal dimensions of 6-hourly, daily maximum and daily minimum for 850 hPa wind speed (a) and wind direction (b).

From Table 4.4 and Figure 4.3b, the 6-hourly, daily maximum and daily minimum 850 hPa wind direction of Chiang Mai has the smallest fractal dimension. That is at this level, wind at Chiang Mai also has the smallest fluctuation in wind direction.

The relative magnitude of fractal dimensions of 850 hPa wind speed and direction for all stations are different.

From Tables 4.2-4.4 and Figures 4.1-4.3, fractal dimensions of surface wind direction and speed are more than those of 850 hPa wind. Thus, surface wind has more fluctuation in wind speed and direction than wind at 850 hPa level, except only the daily minimum wind at CM. This is because at 850 hPa level, wind is free from the influence of earth surface so there is less variation in wind speed and direction. At 850 hPa level, the fractal dimension of wind speed and the fractal dimension of wind direction have different patterns of relative magnitudes for 6-hourly, daily maximum and daily minimum dimension.

**Table 4.5** Fractal dimensions of 850 hPa wind

10-year	Speed				Direction	
	Highest		Lowest		Highest	Lowest
6-hourly	1.227 BK		1.206 CM		1.241 BK	1.205 CM
Daily Max	1.225 UB	1.225 BK	1.220 PK	1.220 SK	1.245 SK	1.220 CM
Daily Min	1.234 BK		1.217 PK		1.241 BK	1.204 CM

From Table 4.5, Bangkok has the highest fractal dimensions for both wind speed and direction for 6-hourly and daily minimum data. For the lowest fractal dimension, Chiang Mai has the lowest values for both wind speed and direction for 6-hourly data.

### 4.3 Fractal Dimension of Yearly Summer Monsoon Wind

The fractal dimensions of 6 hourly, daily minimum and daily maximum surface wind for five wind stations; CM, UB, PK, SK and BK, for yearly (2003 to 2012) data are shown in this Section.

#### 4.3.1 Fractal Dimension of Surface Wind (Case C)

Fractal dimensions of surface wind speed and direction are shown in Tables 4.6-4.10 and Figures 4.4- 4.8.

**Table 4.6** Fractal dimensions of surface wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Chiang Mai.

Year	Chiang Mai (CM)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.246	1.275	1.223	1.306	1.293	1.137
2004	1.241	1.290	1.241	1.318	1.302	1.302
2005	1.238	1.347	1.290	1.289	1.335	1.271
2006	1.242	1.312	1.232	1.300	1.280	1.196
2007	1.245	1.286	1.197	1.304	1.324	1.207
2008	1.236	1.289	1.202	1.305	1.305	1.141
2009	1.227	1.346	1.150	1.293	1.332	1.158
2010	1.231	1.315	1.392	1.289	1.332	1.397
2011	1.237	1.324	1.181	N/A	N/A	N/A
2012	1.193	1.331	1.173	1.257	1.342	1.173

**Table 4.7** Fractal dimensions of surface wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Ubon Ratchathani.

Year	Ubon Ratchatani (UB)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.239	1.274	1.315	1.293	1.325	1.239
2004	1.249	1.284	1.325	1.309	1.390	1.242
2005	1.261	1.339	1.259	1.335	1.333	1.229
2006	1.238	1.296	1.303	1.323	1.333	1.278
2007	1.237	1.252	1.287	1.327	1.304	1.278
2008	1.230	1.285	1.270	1.297	1.348	1.249
2009	1.228	1.293	1.303	1.295	1.305	1.234
2010	1.235	1.284	1.275	1.311	1.356	1.266
2011	1.228	1.281	1.250	1.311	1.326	1.297
2012	1.223	1.281	1.294	1.323	1.382	1.244

**Table 4.8** Fractal dimensions of surface wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Phuket.

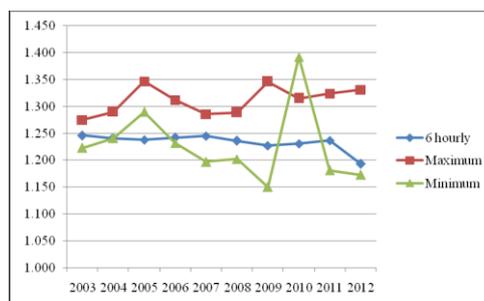
Year	Phuket (PK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.223	1.272	1.188	1.292	1.261	1.212
2004	1.197	1.279	1.208	1.284	1.332	1.199
2005	1.215	1.302	1.225	1.289	1.260	1.219
2006	1.225	1.286	1.278	1.285	1.287	1.293
2007	1.206	1.277	1.259	1.282	1.293	1.230
2008	1.205	1.267	1.236	1.290	1.291	1.220
2009	1.244	1.278	1.268	1.278	1.213	1.288
2010	1.227	1.260	1.219	1.279	1.281	1.233
2011	1.217	1.267	1.288	1.263	1.244	1.301
2012	1.204	1.277	1.235	1.292	1.242	1.259

**Table 4.9** Fractal dimensions of surface wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Songkhla.

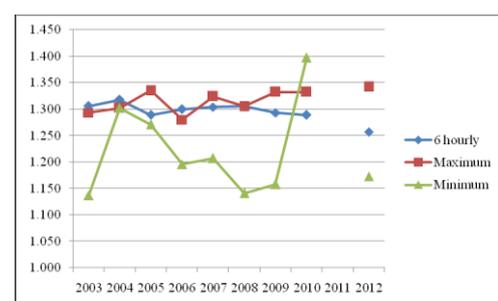
Year	Songkhla (SK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.201	1.266	1.147	1.283	1.265	1.196
2004	1.181	1.280	1.354	1.284	1.286	1.411
2005	1.200	1.282	N/A	1.305	1.277	N/A
2006	1.202	1.274	1.174	1.288	1.275	1.191
2007	1.214	1.305	1.170	1.287	1.271	1.176
2008	1.222	1.293	N/A	1.305	1.245	N/A
2009	1.226	1.278	1.301	1.275	1.300	1.304
2010	1.223	1.297	1.241	1.282	1.282	1.232
2011	1.236	1.308	1.267	1.307	1.290	1.261
2012	1.228	1.280	1.289	1.292	1.304	1.256

**Table 4.10** Fractal dimensions of surface wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Bangkok.

Year	Bangkok (BK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.243	1.299	1.225	1.297	1.293	1.137
2004	1.248	1.295	1.251	1.290	1.302	1.302
2005	1.247	1.286	1.246	1.303	1.335	1.271
2006	1.256	1.272	1.214	1.288	1.280	1.196
2007	1.225	1.272	1.232	1.297	1.324	1.207
2008	1.228	1.306	1.347	1.304	1.305	1.141
2009	1.215	1.309	1.179	1.290	1.332	1.158
2010	1.195	1.271	1.116	1.280	1.332	1.397
2011	1.219	1.317	1.217	1.263	1.275	1.065
2012	1.195	1.303	1.193	1.288	1.342	1.173

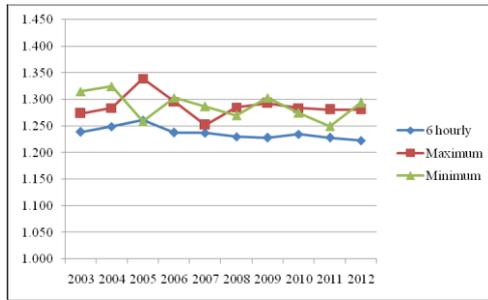


(a)

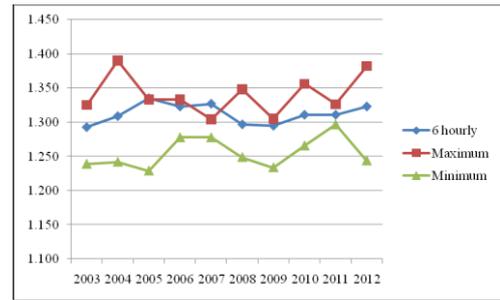


(b)

**Figure 4.4** Fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed (a) and wind direction (b) at Chiang Mai.

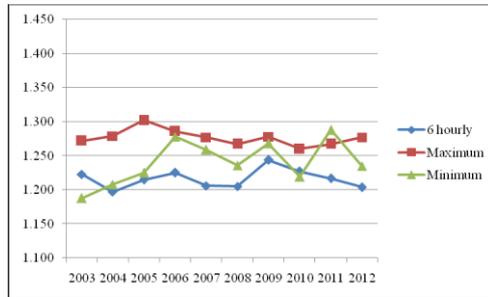


(a)

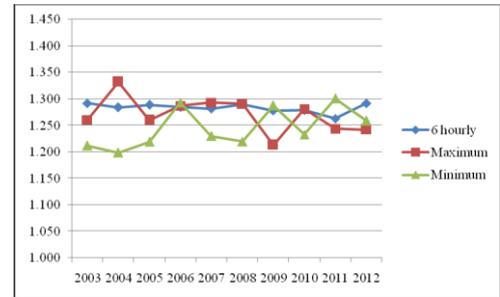


(b)

**Figure 4.5** Fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed (a) and wind direction (b) at Ubon Ratchathani.

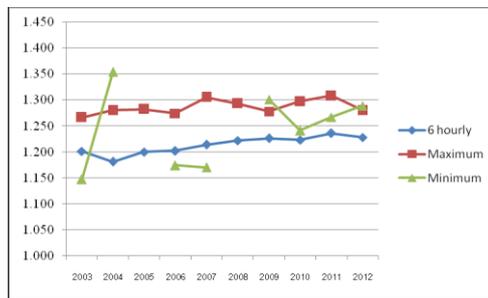


(a)

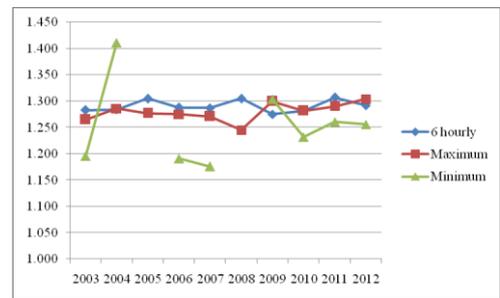


(b)

**Figure 4.6** Fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed (a) and wind direction (b) at Phuket.

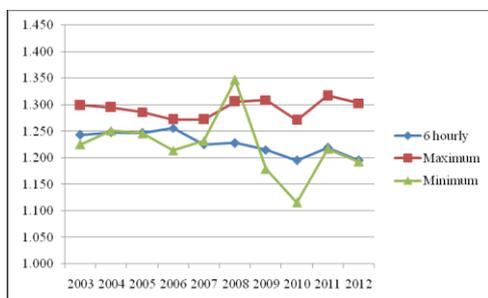


(a)

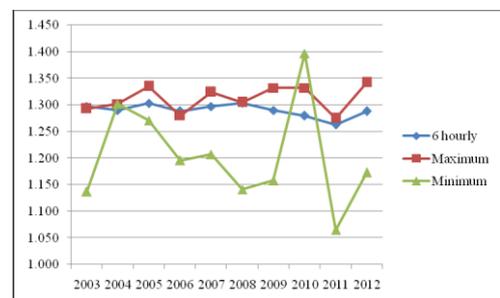


(b)

**Figure 4.7** Fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed (a) and wind direction (b) at Songkhla.



(a)



(b)

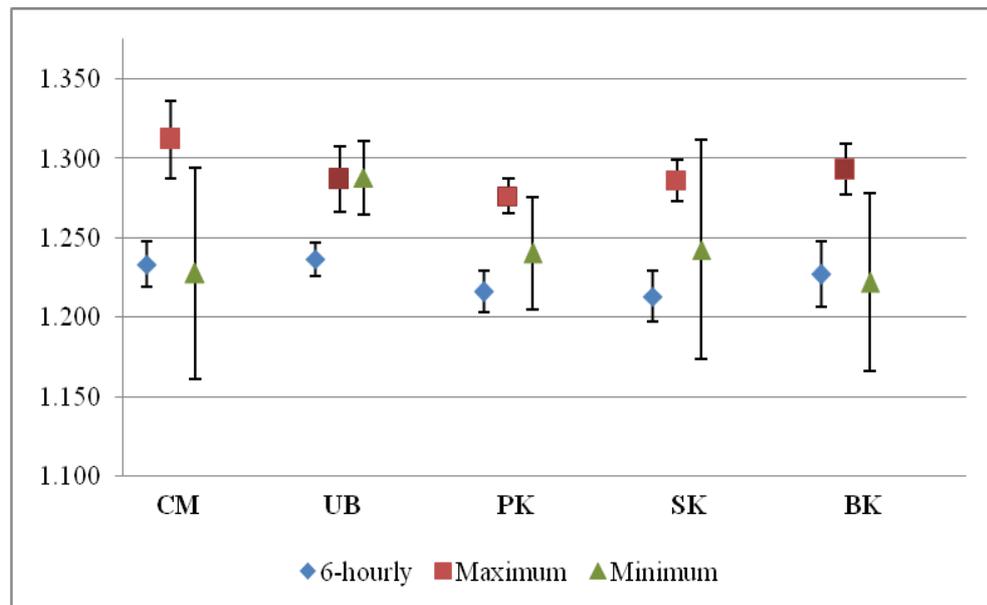
**Figure 4.8** Fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed (a) and wind direction (b) at Bangkok.

Tables 4.6-4.10 and Figures 4.4-4.8 show that the relative magnitude of fractal dimensions of surface wind speed and direction for CM and BK are similar. While fractal dimension of daily minimum wind direction is smallest in 2011 at BK.

Table 4.11 and Figure 4.9 show the averages and standard deviations of yearly fractal analyses for all stations for surface wind speed. The standard deviation of daily maximum is larger than those of 6-hourly and daily minimum for all stations.

**Table 4.11** Average and standard deviation of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed from 2003-2012 over Thailand.

Province	6-hourly		Daily-Max		Daily-Min	
	Mean	SD	Mean	SD	Mean	SD
CM	1.2336	0.0146	1.3120	0.0244	1.2280	0.0663
UB	1.2368	0.0107	1.2869	0.0208	1.2881	0.0232
PK	1.2163	0.0133	1.2765	0.0111	1.2404	0.0354
SK	1.2133	0.0160	1.2863	0.0131	1.2429	0.0686
BK	1.2271	0.0205	1.2930	0.0160	1.2220	0.0558

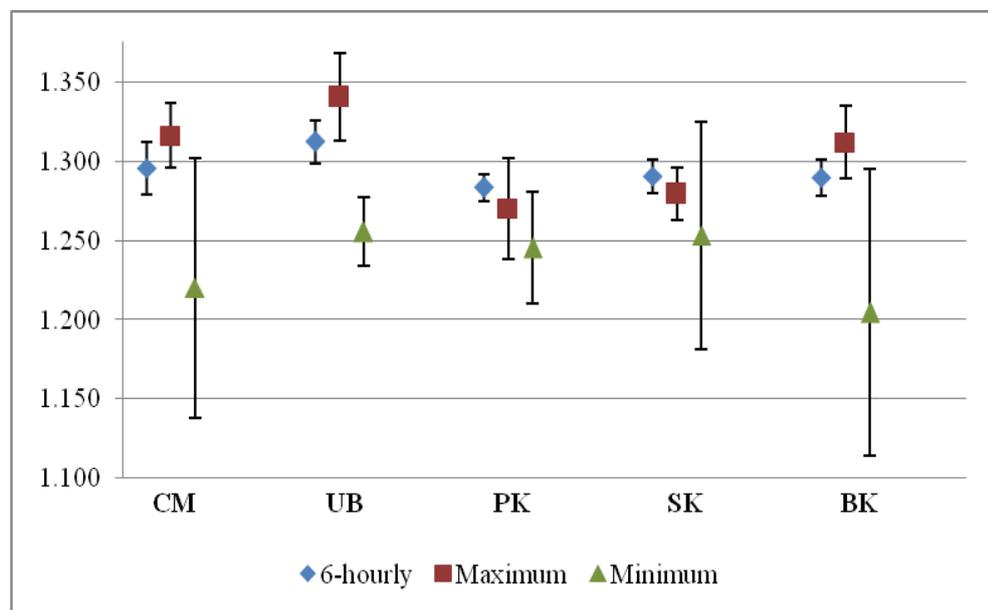


**Figure 4.9** Average and standard deviation of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind speed from 2003-2012 over Thailand.

Table 4.12 and Figure 4.10 show the averages and standard deviations of yearly analyses for all stations for surface wind direction. The standard deviation of daily maximum is larger than those of 6-hourly and daily minimum for all stations.

**Table 4.12** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind direction from 2003-2012 over Thailand.

Province	6-hourly		Daily-Max		Daily-Min	
	Mean	SD	Mean	SD	Mean	SD
CM	1.2957	0.0162	1.3161	0.0204	1.2202	0.0820
UB	1.3124	0.0137	1.3402	0.0276	1.2556	0.0215
PK	1.2834	0.0083	1.2704	0.0318	1.2454	0.0352
SK	1.2908	0.0106	1.2795	0.0164	1.2534	0.0717
BK	1.2900	0.0114	1.3120	0.0230	1.2047	0.0907



**Figure 4.10** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum surface wind direction from 2003-2012 over Thailand.

Summary of the results for yearly surface wind are shown in Tables 4.13 and 4.14.

**Table 4.13** Highest and lowest fractal dimensions of yearly (2003-2012) surface wind speed.

Year	6-hourly		Daily Max		Daily Min	
	Highest	Lowest	Highest	Lowest	Highest	Lowest
2003	1.246 CM	1.201 SK	1.299 BK	1.272 PK	1.315 UB	1.118 PK
2004	1.249 UB	1.181 SK	1.295 BK	1.279 PK	1.315 UB	1.147 SK
2005	1.261 UB	1.200 SK	1.347 CM	1.282 SK	1.290 CM	1.225 PK
2006	1.256 BK	1.202 SK	1.312 CM	1.272 BK	1.303 UB	1.174 SK
2007	1.245 CM	1.206 PK	1.305 SK	1.252 UB	1.287 UB	1.170 SK
2008	1.236 CM	1.205 PK	1.236 CM	1.205 PK	1.347 BK	1.203 CM
2009	1.228 UB	1.215 BK	1.228 BK	1.215 UB	1.303 UB	1.150 CM
2010	1.235 UB	1.195 BK	1.315 CM	1.260 PK	1.392 CM	1.116 BK
2011	1.237 CM	1.217 PK	1.324 CM	1.267 PK	1.288 PK	1.181 CM
2012	1.228 SK	1.193 CM	1.331 CM	1.277 PK	1.294 UB	1.173 CM

**Table 4.14** Highest and lowest fractal dimensions of yearly (2003-2012) surface wind direction.

Year	6-hourly			Daily Max			Daily Min					
	Highest		Lowest	Highest		Lowest	Highest		Lowest			
2003	1.306 CM		1.283 UB		1.325 UB		1.261 PK		1.239 UB		1.137 CM	1.271 BK
2004	1.318 CM		1.284 PK	1.284 SK	1.390 UB		1.286 SK		1.411 SK		1.199 PK	
2005	1.335 UB		1.289 CM	1.289 PK	1.335 CM	1.335 BK	1.260 PK		1.271 CM	1.271 BK	1.219 PK	
2006	1.323 UB		1.285 PK		1.333 UB		1.275 SK		1.293 PK		1.191 SK	
2007	1.327 UB		1.282 PK		1.324 CM		1.271 BK	1.271 SK	1.278 UB		1.176 SK	
2008	1.305 CM	1.305 SK	1.290 PK		1.348 UB		1.245 SK		1.249 UB		1.141 CM	1.141 BK
2009	1.295 UB		1.275 SK		1.332 CM	1.332 BK	1.213 PK		1.304 SK		1.158 CM	1.158 BK
2010	1.311 UB		1.279 PK		1.356 UB		1.281 PK		1.397 CM,BK		1.232 SK	
2011	1.311 UB		1.263 PK	1.263 BK	1.326 UB		1.244 PK		1.301 PK		1.065 BK	
2012	1.323 UB		1.257 CM		1.382 UB		1.242 PK		1.259 PK		1.173 CM	1.173 BK

### 4.3.2 Fractal Dimension of 850 hPa Wind (Case D)

Fractal dimensions of 850 hPa wind speed and direction are shown in Tables 4.15-4.19 and Figures 4.11- 4.15.

**Table 4.15** Fractal dimensions of 850 hPa wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Chiang Mai.

Year	Chiang Mai (CM)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.217	1.226	1.230	1.219	1.236	1.240
2004	1.217	1.191	1.204	1.260	1.244	1.184
2005	1.200	1.243	1.243	1.184	1.241	1.216
2006	1.209	1.243	1.251	1.218	1.239	1.201
2007	1.202	1.245	1.247	1.211	1.267	1.248
2008	1.225	1.271	1.280	1.217	1.243	1.229
2009	1.228	1.199	1.233	1.201	1.223	1.200
2010	1.214	1.190	1.222	1.179	1.175	1.154
2011	1.225	1.245	1.242	1.190	1.185	1.208
2012	1.208	1.241	1.238	1.190	1.207	1.228

**Table 4.16** Fractal dimensions of 850 hPa wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Ubon Ratchathani.

Year	Ubon Ratchatani (UB)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.235	1.241	1.245	1.206	1.185	1.218
2004	1.220	1.218	1.235	1.277	1.293	1.233
2005	1.208	1.243	1.249	1.206	1.239	1.239
2006	1.206	1.242	1.248	1.209	1.227	1.226
2007	1.203	1.224	1.236	1.223	1.252	1.252
2008	1.232	1.282	1.263	1.226	1.264	1.241
2009	1.242	1.190	1.240	1.204	1.223	1.219
2010	1.229	1.197	1.214	1.175	1.181	1.176
2011	1.234	1.253	1.252	1.210	1.199	1.213
2012	1.210	1.238	1.240	1.208	1.220	1.254

**Table 4.17** Fractal dimensions of 850 hPa wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Phuket.

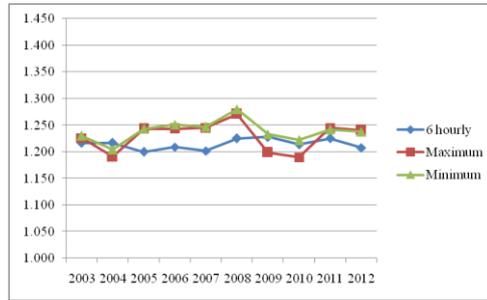
Year	Phuket (PK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.240	1.232	1.239	1.175	1.201	1.154
2004	1.237	1.243	1.235	1.263	1.243	1.312
2005	1.207	1.234	1.235	1.207	1.253	1.245
2006	1.201	1.227	1.231	1.227	1.273	1.242
2007	1.214	1.218	1.223	1.219	1.217	1.238
2008	1.236	1.274	1.269	1.233	1.238	1.266
2009	1.249	1.215	1.227	1.226	1.212	1.225
2010	1.241	1.212	1.199	1.186	1.209	1.197
2011	1.242	1.237	1.236	1.225	1.249	1.220
2012	1.228	1.232	1.238	1.256	1.256	1.250

**Table 4.18** Fractal dimensions of 850 hPa wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Songkhla.

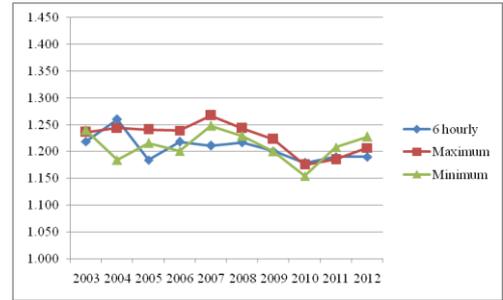
Year	Songkhla (SK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.241	1.226	1.239	1.197	1.199	1.174
2004	1.245	1.257	1.231	1.254	1.223	1.292
2005	1.211	1.219	1.227	1.207	1.239	1.227
2006	1.206	1.223	1.229	1.263	1.270	1.264
2007	1.214	1.218	1.237	1.242	1.208	1.274
2008	1.239	1.263	1.274	1.223	1.232	1.246
2009	1.235	1.227	1.238	1.234	1.214	1.215
2010	1.229	1.222	1.218	1.224	1.194	1.233
2011	1.235	1.250	1.265	1.247	1.236	1.250
2012	1.230	1.230	1.242	1.286	1.236	1.270

**Table 4.19** Fractal dimensions of 850 hPa wind speed and wind direction for 6-hourly, daily maximum and daily minimum wind at Bangkok.

Year	Bangkok (BK)					
	Wind Speed			Wind Direction		
	6-hourly	Daily Max	Daily Min	6-hourly	Daily Max	Daily Min
2003	1.242	1.231	1.241	1.207	1.221	1.194
2004	1.249	1.268	1.245	1.284	1.261	1.275
2005	1.228	1.234	1.237	1.222	1.263	1.237
2006	1.219	1.225	1.247	1.247	1.265	1.260
2007	1.220	1.232	1.246	1.239	1.223	1.266
2008	1.233	1.263	1.290	1.244	1.256	1.280
2009	1.234	1.235	1.241	1.231	1.232	1.232
2010	1.235	1.245	1.237	1.245	1.256	1.227
2011	1.244	1.231	1.269	1.259	1.257	1.265
2012	1.225	1.231	1.240	1.290	1.244	1.284

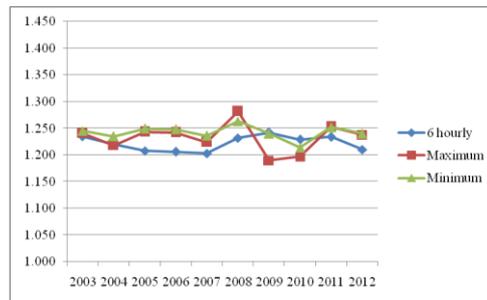


(a)

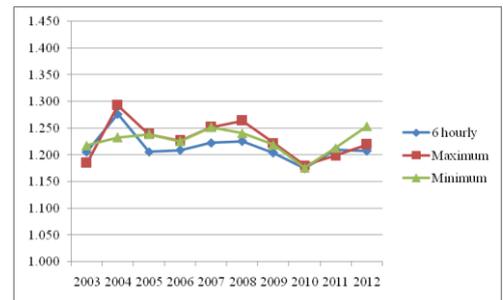


(b)

**Figure 4.11** Fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed (a) and wind direction (b) at Chiang Mai.

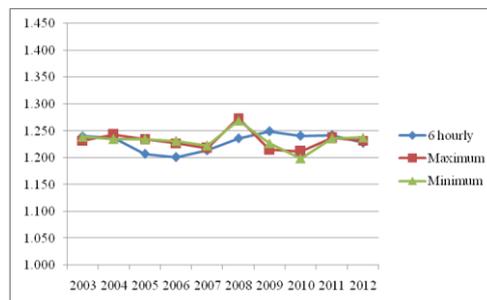


(a)

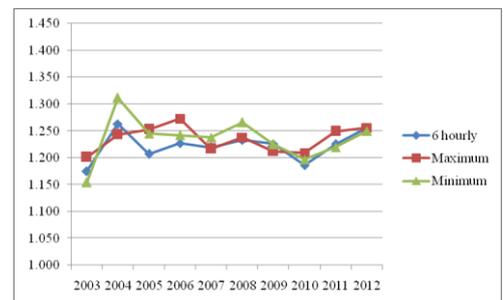


(b)

**Figure 4.12** Fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed (a) and wind direction (b) at Ubon Ratchathani.

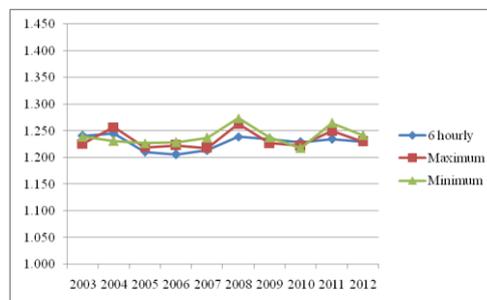


(a)

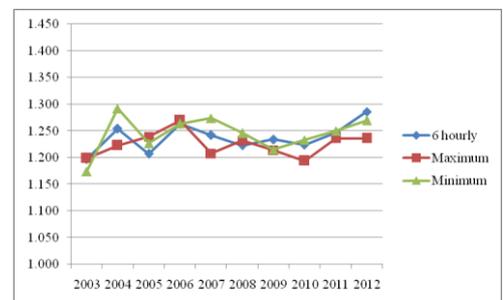


(b)

**Figure 4.13** Fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed (a) and wind direction (b) at Phuket.

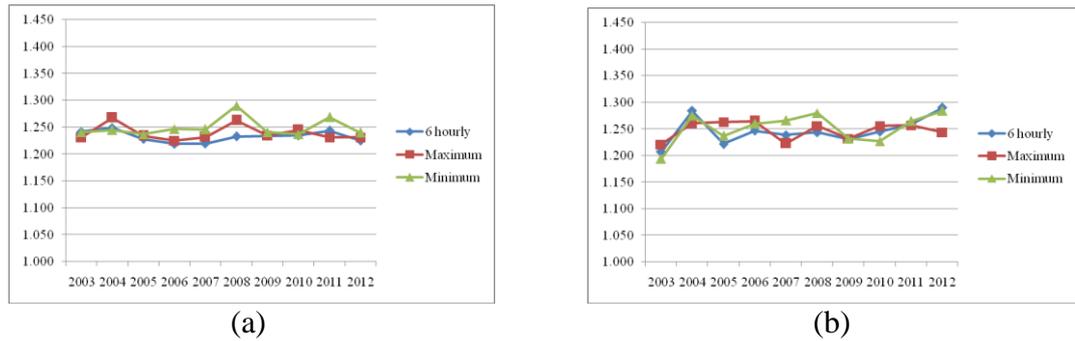


(a)



(b)

**Figure 4.14** Fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed (a) and wind direction (b) at Songkhla.



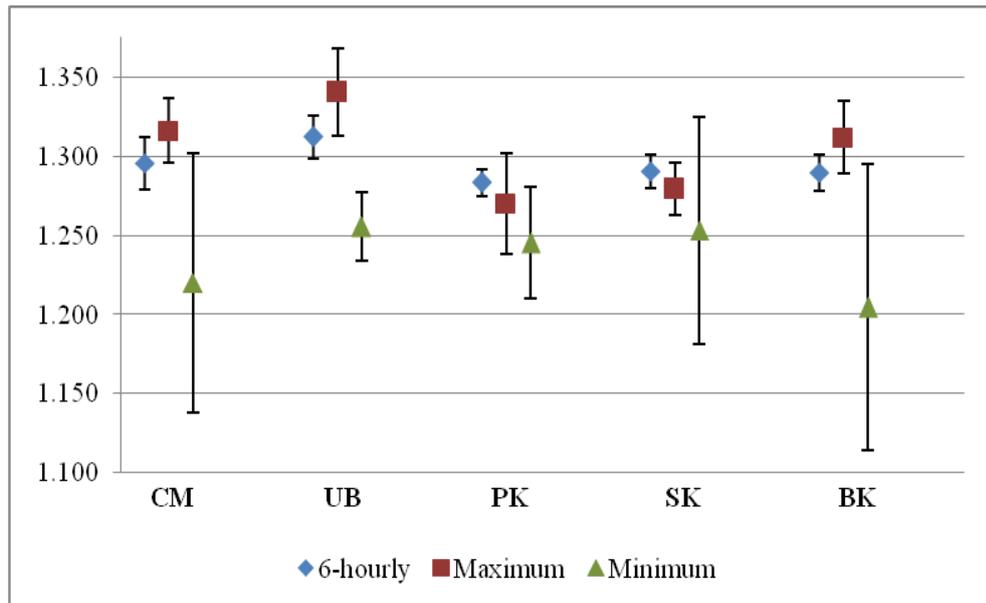
**Figure 4.15** Fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed (a) and wind direction (b) at Bangkok.

Tables 4.15-4.19 and Figures 4.11-4.15 show that the relative magnitude of fractal dimensions of 850 hPa wind speed and direction for SK and BK are different. While fractal dimension of daily minimum wind direction is smallest in 2003 and 2010 at PK and CM respectively.

Table 4.20 and Figure 4.16 show the averages and standard deviations of yearly fractal dimensions for 850 hPa wind speed. The standard deviation of daily maximum is larger than those of 6-hourly and daily minimum for CM and UB.

**Table 4.20** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed from 2003-2012 over Thailand.

Province	6-hourly		Daily-Max		Daily-Min	
	Mean	SD	Mean	SD	Mean	SD
CM	1.2145	0.0092	1.2294	0.0259	1.2390	0.0188
UB	1.2219	0.0135	1.2328	0.0255	1.2422	0.0123
PK	1.2295	0.0156	1.2324	0.0168	1.2332	0.0163
SK	1.2285	0.0128	1.2335	0.0158	1.2400	0.0163
BK	1.2329	0.0096	1.2395	0.0139	1.2493	0.0161

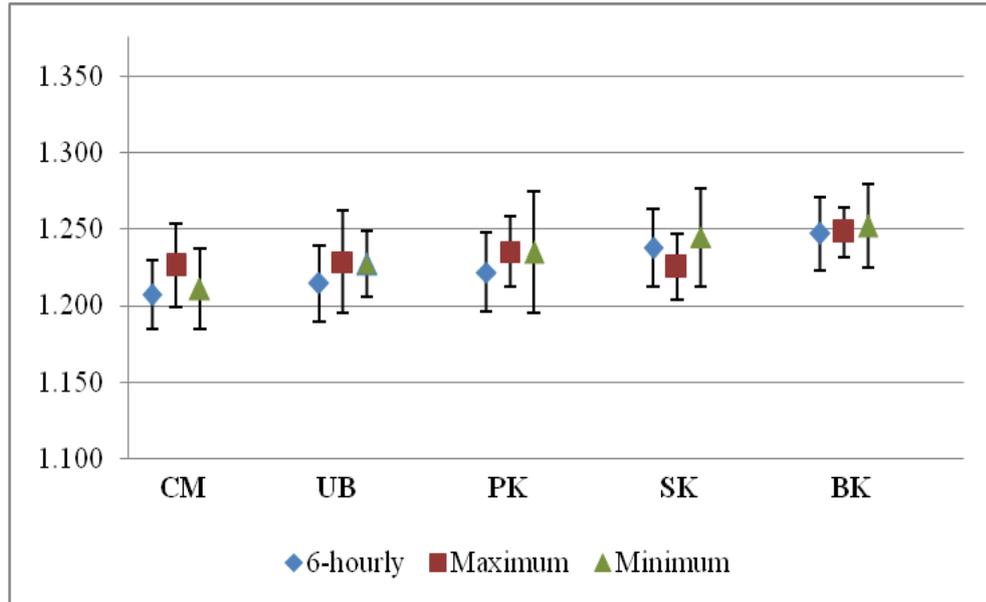


**Figure 4.16** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind speed from 2003-2012 over Thailand.

Table 4.21 and Figure 4.17 show the averages and standard deviation of yearly fractal dimensions for 850 hPa wind direction. The differences of standard deviation among the 6-hourly, daily maximum and daily minimum are smaller than those of the surface wind.

**Table 4.21** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind direction from 2003-2012 over Thailand.

Province	6-hourly		Daily-Max		Daily-Min	
	Mean	SD	Mean	SD	Mean	SD
CM	1.2069	0.0226	1.2260	0.0273	1.2108	0.0266
UB	1.2144	0.0245	1.2283	0.0335	1.2271	0.0216
PK	1.2217	0.0260	1.2351	0.0227	1.2349	0.0395
SK	1.2377	0.0252	1.2251	0.0214	1.2445	0.0324
BK	1.2468	0.0243	1.2478	0.0159	1.2520	0.0272



**Figure 4.17** Averages and standard deviations of yearly fractal dimensions of 6-hourly, daily maximum and daily minimum 850 hPa wind direction from 2003-2012 over Thailand.

Summary of the results for yearly 850 hPa wind are shown in Tables 4.22 and 4.23.

**Table 4.22** Highest and lowest fractal dimensions of yearly (2003-2012) 850 hPa wind speed.

Year	6-hourly		Daily Max			Daily Min		
	Highest	Lowest	Highest	Lowest		Highest	Lowest	
2003	1.242 BK	1.217 CM	1.241 UB	1.226 CM	1.226 SK	1.245 UB	1.230 CM	
2004	1.249 BK	1.217 CM	1.249 BK	1.191 CM		1.245 BK	1.204 CM	
2005	1.228 BK	1.200 CM	1.243 CM	1.243 UB	1.219 SK	1.249 UB	1.227 SK	
2006	1.219 BK	1.201 PK	1.243 CM		1.223 SK	1.251 CM	1.229 SK	
2007	1.220 BK	1.202 CM	1.245 CM	1.218 PK	1.218 SK	1.247 CM	1.223 PK	
2008	1.239 SK	1.225 CM	1.282 UB	1.263 SK	1.263 BK	1.290 BK	1.263 UB	
2009	1.249 PK	1.228 CM	1.235 BK	1.190 UB		1.241 BK	1.227 PK	
2010	1.241 PK	1.214 CM	1.190 CM	1.245 BK		1.237 BK	1.199 PK	
2011	1.244 BK	1.225 CM	1.253 UB	1.231 BK		1.269 BK	1.236 PK	
2012	1.230 SK	1.208 CM	1.241 CM	1.230 SK		1.242 SK	1.238 CM	1.238 PK

**Table 4.23** Highest and lowest fractal dimensions of yearly (2003-2012) 850 hPa wind direction.

Year	6-hourly		Daily Max			Daily Min	
	Highest	Lowest	Highest	Lowest		Highest	Lowest
2003	1.219 CM	1.175 PK	1.241 UB	1.226 CM	1.226 SK	1.240 CM	1.154 PK
2004	1.284 BK	1.254 SK	1.268 BK	1.191 CM		1.312 PK	1.184 CM
2005	1.222 BK	1.184 CM	1.243 UB	1.219 CM	1.219 SK	1.245 PK	1.216 CM
2006	1.263 SK	1.209 UB	1.243 CM	1.223 SK		1.264 SK	1.201 CM
2007	1.242 SK	1.211 CM	1.245 CM	1.218 PK	1.218 SK	1.274 SK	1.238 PK
2008	1.244 BK	1.217 CM	1.282 UB	1.263 SK	1.263 BK	1.280 BK	1.229 CM
2009	1.234 SK	1.201 CM	1.235 BK	1.190 UB		1.232 BK	1.2 CM
2010	1.245 BK	1.175 UB	1.245 BK	1.190 CM		1.233 SK	1.154 CM
2011	1.259 BK	1.190 CM	1.253 UB	1.231 BK		1.265 BK	1.208 CM
2012	1.290 BK	1.190 CM	1.241 CM	1.230 SK		1.284 BK	1.228 CM

