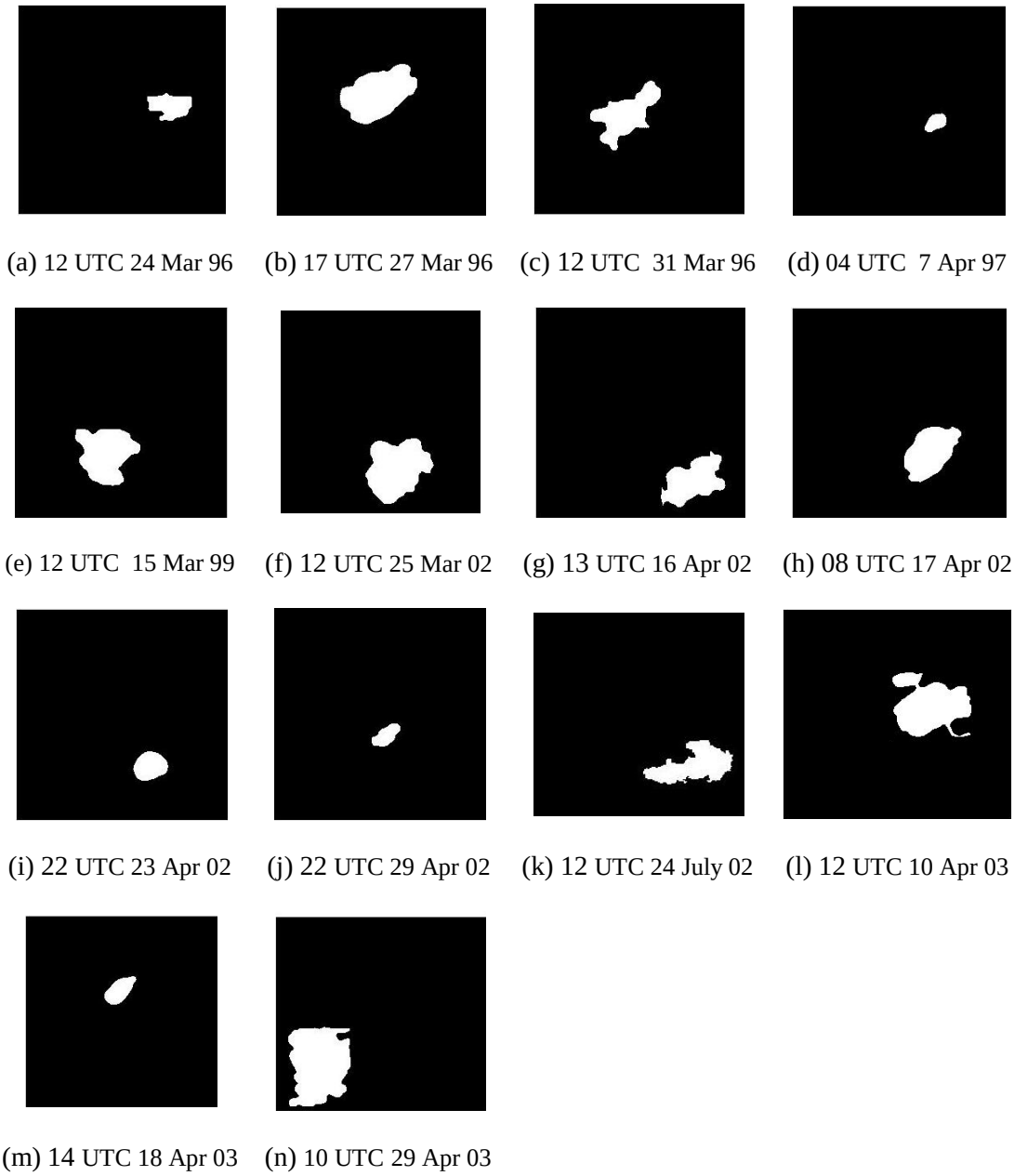
CHAPTER 4 RESULTS AND DISCUSSION

4.1 Cloud Area

Figure 4.1 shows the areas of severe thunderstorm clouds in satellite images of the experiment cases in Table 3.4. The cloud area is obtained as explained is Step 3 in Section 3.2. The areas shown in Figure 4.1 are at the time when the severe thunderstorms are at the mature stage. Areas of all severe thunderstorm clouds for 1-hr before, mature and 1-hr after stages are shown in Appendix A.



(a) 12 UTC 24 Mar 96 (b) 17 UTC 27 Mar 96 (c) 12 UTC 31 Mar 96 (d) 04 UTC 7 Apr 97

(e) 12 UTC 15 Mar 99 (f) 12 UTC 25 Mar 02 (g) 13 UTC 16 Apr 02 (h) 08 UTC 17 Apr 02

(i) 22 UTC 23 Apr 02 (j) 22 UTC 29 Apr 02 (k) 12 UTC 24 July 02 (l) 12 UTC 10 Apr 03

(m) 14 UTC 18 Apr 03 (n) 10 UTC 29 Apr 03

Figure 4.1 Areas of severe thunderstorm clouds.

The areas of non-severe thunderstorm clouds from Table 3.5 are shown in Figure 4.2. Areas of all non-severe thunderstorm clouds for 1-hr before, mature and 1-hr after stages are shown in Appendix B.

(a) 16 UTC 17 April 01 (b) 11 UTC 16 July 01 (c) 19 UTC 12 December 01

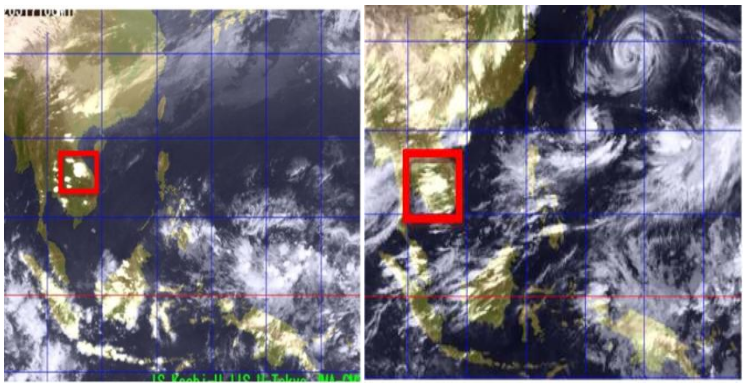
(d) 09 UTC 19 April 02 (e) 01 UTC 16 July 02 (f) 13 UTC 16 November 02

Figure 4.2 Areas of non-severe thunderstorm clouds.

4.2 Fractal Dimension of Severe Thunderstorm Clouds

The overlapping area-perimeter method is used to identify the fractal dimension of severe thunderstorm clouds from the experiment cases shown in Table 3.4. Details of calculation for the cases of 17 April 2002 (summer) and 24 July 2002 (rainy season) are shown in this section.

The IR1 images for these 2 cases are shown in Figure 4.3 for (a) 17 April 2002 and (b) 24 July 2002.



(a) 17 April 2002 (b) 24 July 2002.

Figure 4.3 Images for (a) 17 April 2002 and (b) 24 July 2002.

4.2.1 The Case of 17 April 2002

The image for this case is shown in Figure 4.3 (a). This image is cropped to the size of 256×256 pixels. The area and perimeter for various values of reduction factor are shown in Table 4.1 and the corresponding linear regression is shown in Figure 4.4.

Table 4.1 Calculation for the case of 17 April 2002.

Factor *r*	Grid point	Perimeter (r_i)	Log(*P*)	Area (pixel)	Log(*A*)
r_0=0.05°	256×256	227.8650071	2.357678	2998	3.476832
r_1=0.10°	174×174	152.8528137	2.184273	1390	3.143015
r_2=0.20°	65×65	53.69848481	1.729962	184	2.264818
r_3=0.25°	33×33	26.97056275	1.43089	48	1.681241
r_4=0.40°	17×17	12.24264069	1.087875	13	1.113943

The linear regression is shown in Figure 4.4.

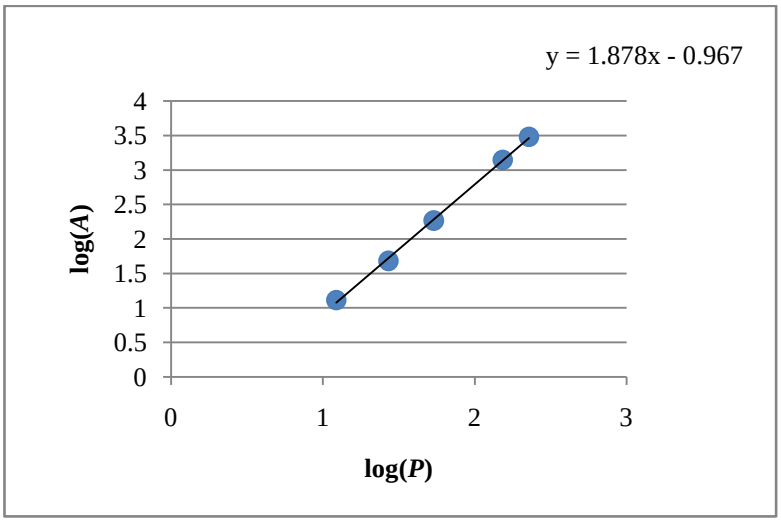


Figure 4.4 Graph representing the slope of the log (*A*) versus log (*P*) for the case of 17 April 2002.

Thus, fractal dimension of the selected cloud in Figure 4.3 (a) is 1.878.

4.2.2 The Case of 24 July 2002

The image for this case is shown in Figure 4.3 (b). This image is cropped to the size of 256×256 pixels. The area and perimeter for various values of reduction factor are shown in Table 4.2 and the corresponding linear regression is shown in Figure 4.5.

Table 4.2 Calculation for the case of 24 July 2002.

Factor *r*	Grid point	Perimeter (r_i)	Log(*P*)	Area (pixel)	Log(*A*)
r_0=0.05°	256×256	294.450793488833	2.469013	1964	3.293141
r_1=0.10°	174×174	135.053823869162	2.130507	492	2.691965
r_2=0.20°	65×65	59.9411254969543	1.777725	121	2.082785
r_3=0.25°	33×33	45.7989898732233	1.660856	78	1.892095
r_4=0.40°	17×17	19.0710678118655	1.280375	18	1.255273

The linear regression is shown in Figure 4.5.

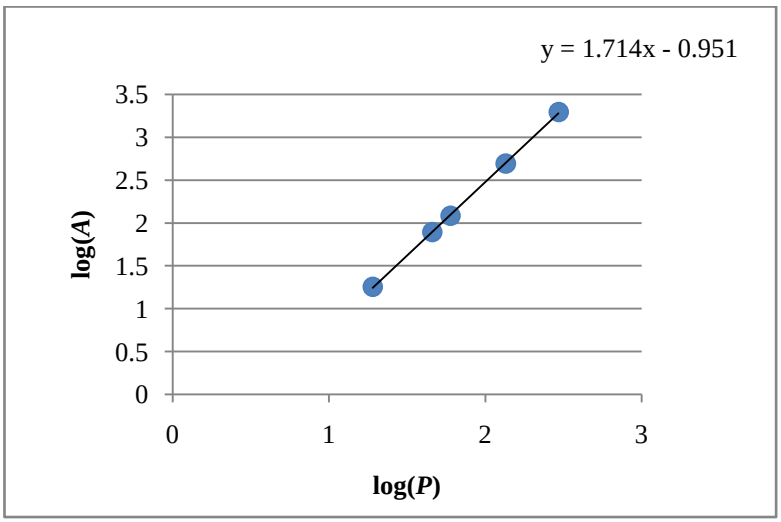


Figure 4.5 Graph representing the slope of the log (*A*) versus log (*P*) for the case of 24 July 2002.

Thus, fractal dimension of the selected cloud in Figure 4.3 (b) is 1.714.

Fractal dimension for all experiment cases are summarized in Table 4.3. In this table, the fractal dimensions for all cases are at the mature stage of the cloud as well as at 1 hour before and 1 hour after the mature stage.

Table 4.3 Fractal dimension of severe thunderstorm clouds.

dd/mm/yy	OAP Fractal dimension		
	1 hr Before	Mature	1 hr After
24 Mar 96	1.423	1.673	1.177
27 Mar 96	1.828	1.852	1.823
31 Mar 96	1.763	1.821	1.739
7 Apr 97	1.450	1.472	1.469
15 Mar 99	1.790	1.861	1.806
25 Mar 02	1.805	1.823	1.760
16 Apr 02	1.711	1.740	1.725
17 Apr 02	1.731	1.878	1.698
23 Apr 02	1.701	1.755	1.747
29 Apr 02	1.451	1.605	1.326
24 July 02	1.599	1.878	1.768
10 Apr 03	1.739	1.816	1.717
18 Apr 03	1.700	1.783	1.764
29 Apr 03	1.664	1.802	1.751
Average	1.668	1.768	1.662

The fractal dimensions for all experiment cases are also shown in Figure 4.6 and the average value of fractal dimension is shown in Figure 4.7.

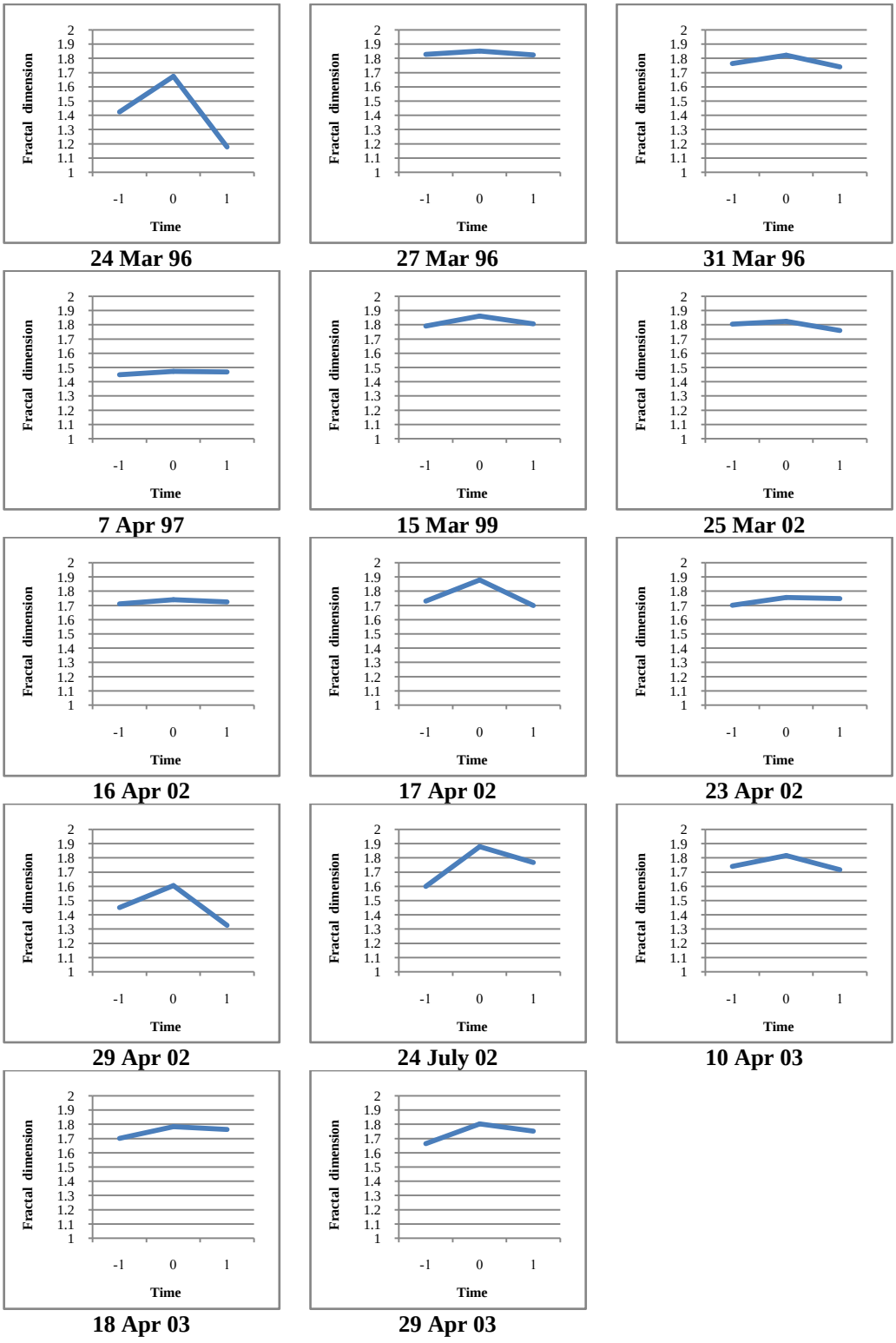


Figure 4.6 Fractal dimensions of severe thunderstorm clouds. Time is hourly interval with respects to the mature stage of the cloud.

Considering Figure 4.6, the experiment cases show that the values of the fractal dimension of severe thunderstorms clouds for 1 hr before, mature and 1 hr after are similar among the cases of 27 March 1996, 31 March 1996, 15 March 1999 and 17 March 2002. However, on 24 March 1996, 25 March 2002, 29 April 2002 and

10 April 2003, the values of the fractal dimension at 1 hr before is more than the values of the fractal dimension 1 hr after. On 7 April 1997, 16 April 2002, 23 April 2002, 24 July 2002, 18 April 2003 and 29 April 2003, the values of the fractal dimension at 1 hr before is less than the values of the fractal dimension 1 hr after.

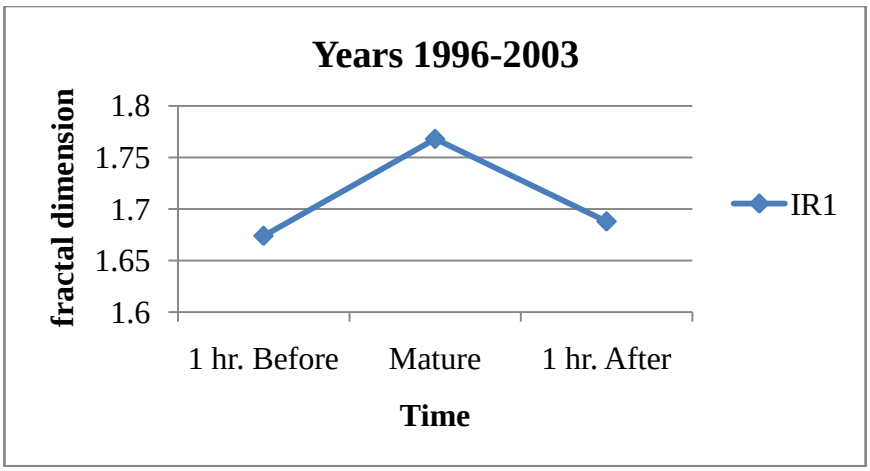


Figure 4.7 Average fractal dimension of severe thunderstorm clouds.

It can be seen from Figure 4.7 that the severe thunderstorm cloud has the largest value of fractal dimension at the mature stage.

Figure 4.8 shows that on 24 March 1996, the fractal dimension for 1 hr before is more than the fractal dimension for 1 hr after.

Figure 4.8 Fractal dimensions of severe thunderstorm clouds on 24 Mar 96.

But for 24 July 2002, the fractal dimension for 1 hr before is less than the fractal dimension for 1 hr after, which can be seen from Figure 4.9.

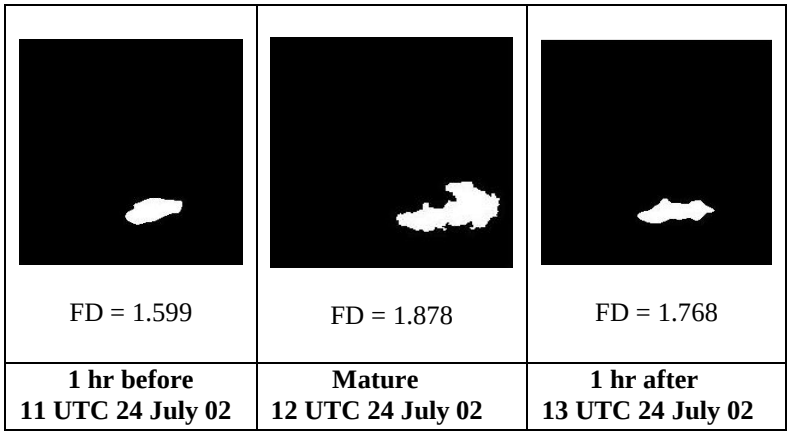


Figure 4.9 Fractal dimensions of severe thunderstorm clouds on 24 July 02.

4.3 Fractal Dimension of Large and Small Severe Thunderstorm Clouds

From Figure 4.1, the severe thunderstorms clouds can be divided into 2 sizes, large cloud and small cloud. The fractal dimension for large cloud and small cloud are shown in Table 4.4 and Table 4.5, respectively.

Table 4.4 Fractal dimensions of large severe thunderstorm clouds.

dd/mm/yy	Fractal dimension for large clouds
27 Mar 96	1.852
31 Mar 96	1.821
15 Mar 99	1.861
25 Mar 02	1.823
10 Apr 03	1.816
29 Apr 03	1.802
Average	1.829

Table 4.5 Fractal dimensions of small severe thunderstorm clouds.

dd/mm/yy	Fractal dimension for small clouds
24 Mar 96	1.673
7 Apr 97	1.472
16 Apr 02	1.74
17 Apr 02	1.878
23 Apr 02	1.755
29 Apr 02	1.605
Average	1.687

From Table 4.4 and Table 4.5, large severe thunderstorm cloud has larger value of fractal dimension than small severe thunderstorm cloud. This result is in agreement with Gotoh and Fujii (1998).

4.4 Fractal Dimension of Non-severe Thunderstorm Clouds

Fractal dimension of non-severe thunderstorm clouds in Figure 4.2 are shown Table 4.6.

Table 4.6 OAP fractal dimensions of non-severe thunderstorm clouds.

dd/mm/yy	Fractal dimension		
	1 hr. Before	Mature	1 hr. After
17-April-01	1.688	1.730	1.658
16-July-01	1.664	1.772	1.683
12-December-01	1.564	1.798	1.644
19-April-02	1.737	1.784	1.771
16- July -02	1.731	1.804	1.732
16- November -02	1.660	1.725	1.642
Average	1.674	1.768	1.688

The averaged fractal dimension of non-severe thunderstorm clouds is 1.710.

The fractal dimensions of non-severe thunderstorm clouds are shown in Figures 4.8 and 4.9.

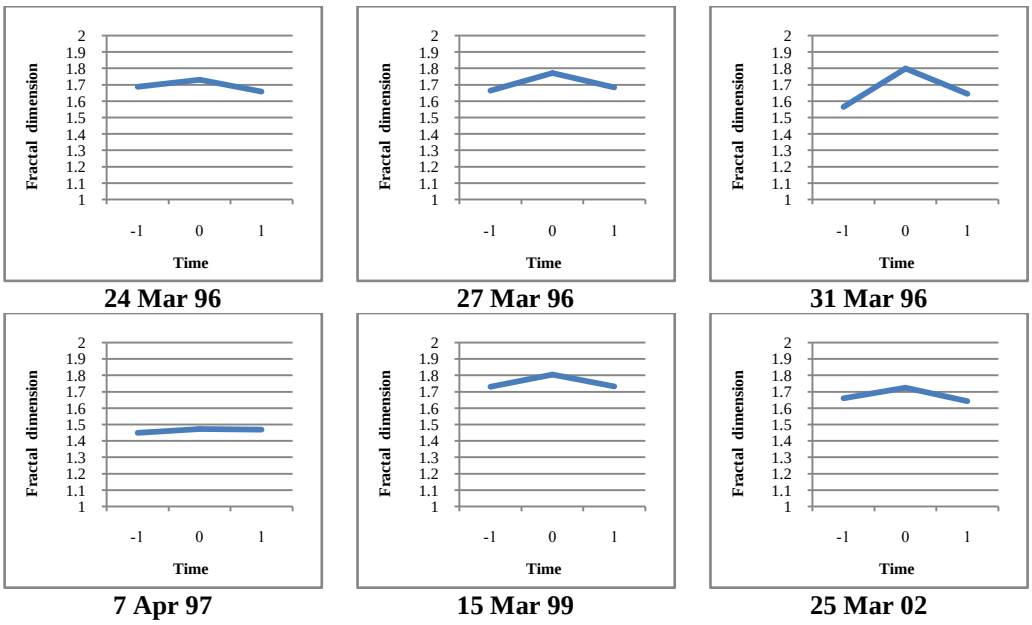


Figure 4.10 Fractal dimensions of non-severe thunderstorm clouds. Time is hourly interval with respects to the mature stage.

From Figure 4.10, the fractal dimensions of all non-severe thunderstorm clouds have similar relative pattern for 1 hr before, mature and 1 hr after values. The average fractal dimension of non-severe thunderstorm clouds is shown in Figure 4.11.

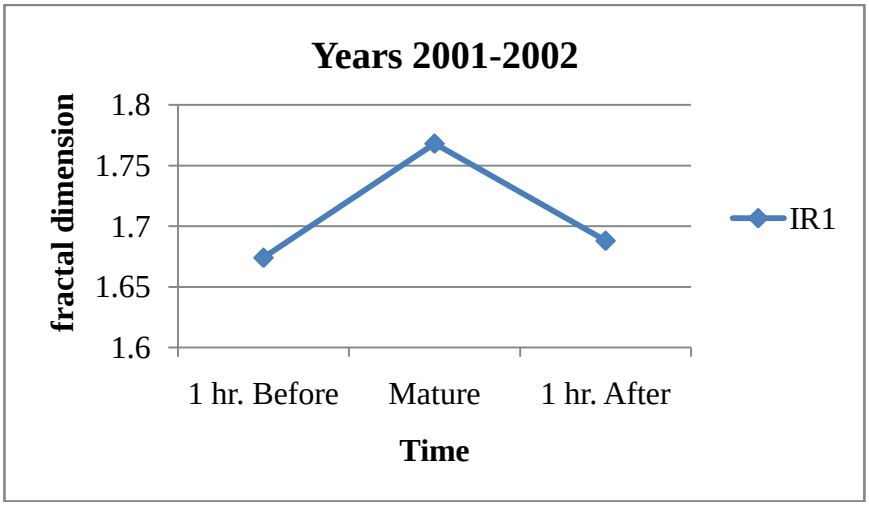


Figure 4.11 Average fractal dimension of non-severe thunderstorm clouds.