

## Chapter 4

### Mapping of Rainfall Data

In this chapter we map the rainfall data for Pattani Province, based on the statistical analysis described in Chapter 3. The methods used could be applied more generally to any data of continuous data type recorded at specified geographical locations in a region on the earth's surface.

Methods for mapping such data are routinely provided by geographical information systems (GIS) software, and are now widely used in practice for many applications. They encompass a large variety of graphical displays and methods, including variograms, kriging, and kernel smoothing (see, for example, Cressie, 1993). However, new methods are needed for mapping such data when the extra dimension time is included.

Although graphical methods for displaying time series data such as time series plots, correlograms and periodograms, have been available for many years and are widely used in practice, these methods have not yet been successfully extended to cover spatial time series.

In this chapter we show how a GIS package can be used to graph the rainfall recorded in Pattani districts over the 19-year period from 1982 to 2000, and we briefly introduce a new method for mapping spatial time series.

#### 4.1 Maps of Average 5-day Rainfall

Figure 4.1 shows a map of Pattani Province with the locations of the rainfall recording stations and the districts shown. Two of the 12 districts (Nong Chik and Khok Pho) each contain two weather stations, and these districts were subdivided, so that for mapping purposes the map of Pattani comprised 14 regions, each associated with independent data.

Figure 4.2 shows a range map of the mean rainfall in a 5-day period at each station, based on the 19 years of data collection from 1982 to 2000, as shown in the first column of Table 3.4. In this case just three colours were used to code the data. The colours chosen were light blue for the lower values (19-23.49 mm), yellow for those in the middle range (23.5-27.49 mm) and light red for the higher values (27.5-36

mm). These colours were chosen because they resemble temperatures: blue is cold and red is hot.

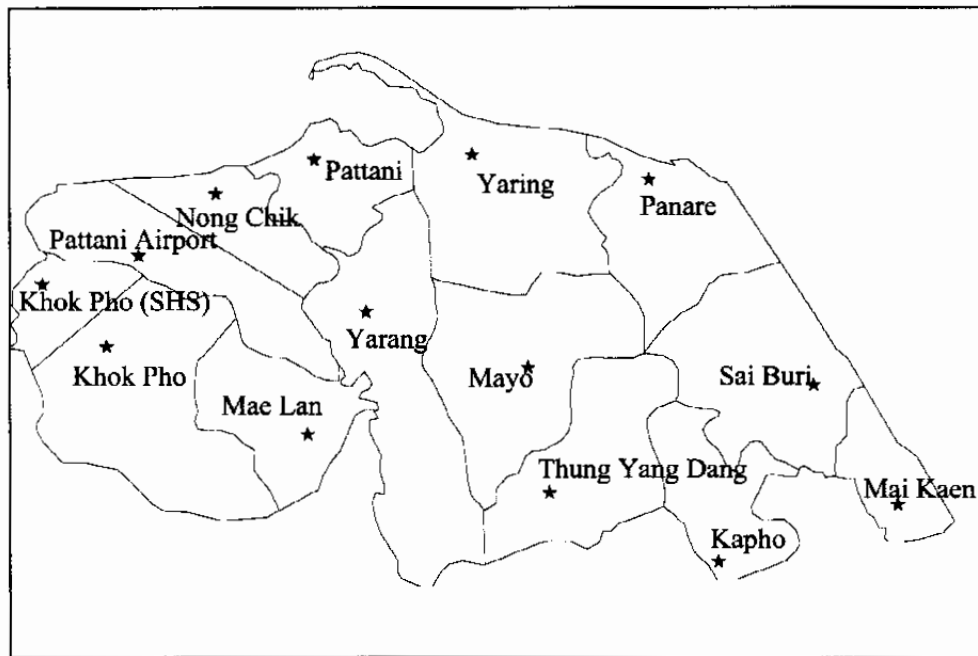


Figure 4.1: Map of Rainfall Recording Stations in Pattani Province

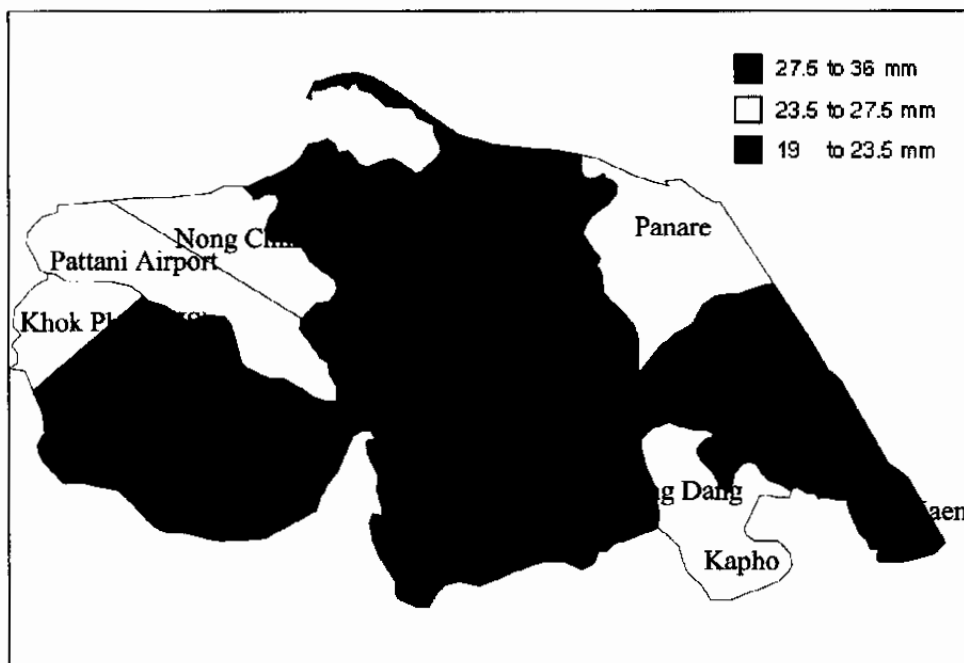


Figure 4.2: Range Map of Mean 5-day Rainfall in Pattani Province

The map of the 5-day rainfall averages shows that five districts (Pattani, Yaring, Thung Yang Dang, Yarang and Khok Pho) had lower than average rainfall, five districts (Khok Pho SHS, Pattani Airport, Nong Chik, Panare and Kapho) had average rainfall, and four districts (Mae Lan, Mayo, Sai Buri and Mai Kaen) had above average rainfall.

Figure 4.3 shows a grid map of the 5-day rainfall means. In this map the data were smoothed spatially, based on a fine grid of coordinates at each position within the mapped region. Six colour bands were used, ranging from dark blue, light blue, green, yellow, light red and dark red. These bands correspond to data in the ranges whose mid-points are shown in the legend for Figure 4.3.



Figure 4.3: Grid Map of Mean 5-day Rainfall in Pattani Province

Figure 4.4 shows a contour map of the same data. In this case the ranges for the colour-coded regions between the contours are as follows.

Dark blue:	Less than 21.25 mm;
Light blue:	21.25 up to 23.75 mm;
Green:	23.75 up to 26.25 mm;
Yellow:	26.25 up to 28.75 mm;
Light Red:	28.75 up to 31.25 mm;

Dark red: 31.25 or greater.

These ranges were chosen to correspond to those used in the grid map.

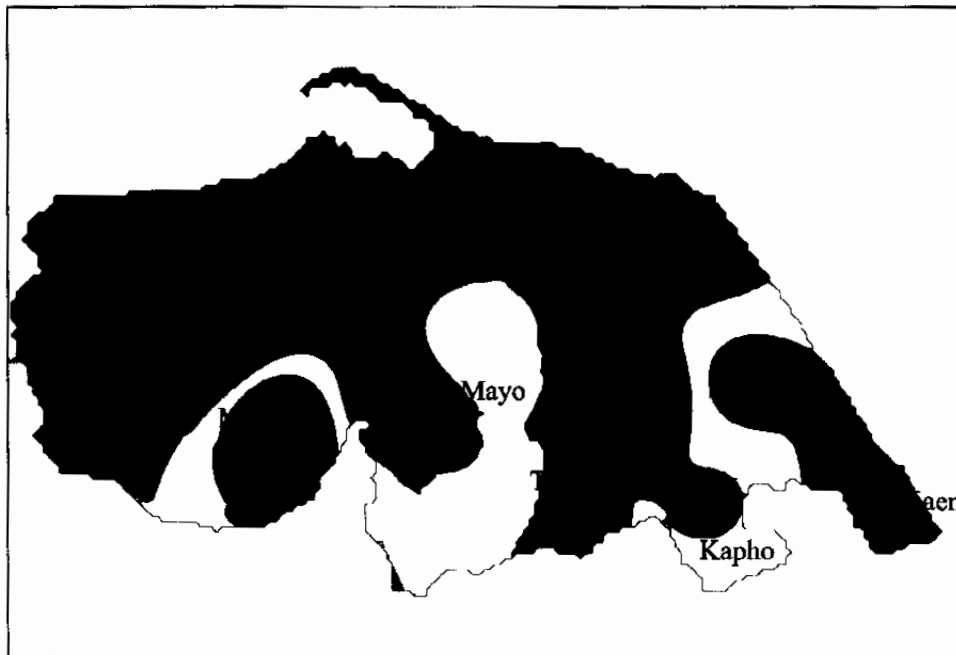


Figure 4.4: Contour Map of Mean 5-day Rainfall in Pattani Province

In Chapter 3, to ensure that the statistical assumptions were satisfied, we applied the transformation  $y = \log(1+x)$  to the 5-day rainfall measurements in millimetres. After carrying out the statistical comparisons of the rainfall in different locations and periods, we converted means back to measurements in millimetres by applying the reverse transformation  $x = 10^y - 1$ . This is very similar to using the geometric mean rather than the arithmetic mean to summarise a sample of data. Given that the distribution of the rainfall was substantially skewed, this method provided more stable estimates.

Figure 4.5 shows a range map of the zero-adjusted geometric (ZAG) mean rainfall in a 5-day period at each station, based on the 19 years of data collection from 1982 to 2000, as shown in the right-hand column of Table 3.4. The same three colours were used to code the data as for Figure 4.2, but in this case the ranges were taken as 0-5 mm (light blue), 5-6.5 (yellow), and 6.5-9 (light red).

Comparing Figures 4.2 and 4.5, the patterns differ. The differences occur in two districts (Yarang and Thung Yang Dang) with low arithmetic means but average ZAG

means, two districts (Nong Chik and Kapho) with average arithmetic means but low ZAG means, one district (Mayo) with a high arithmetic mean but an average ZAG mean, and one district (Pattani Airport) with average arithmetic mean but high ZAG mean rainfall.

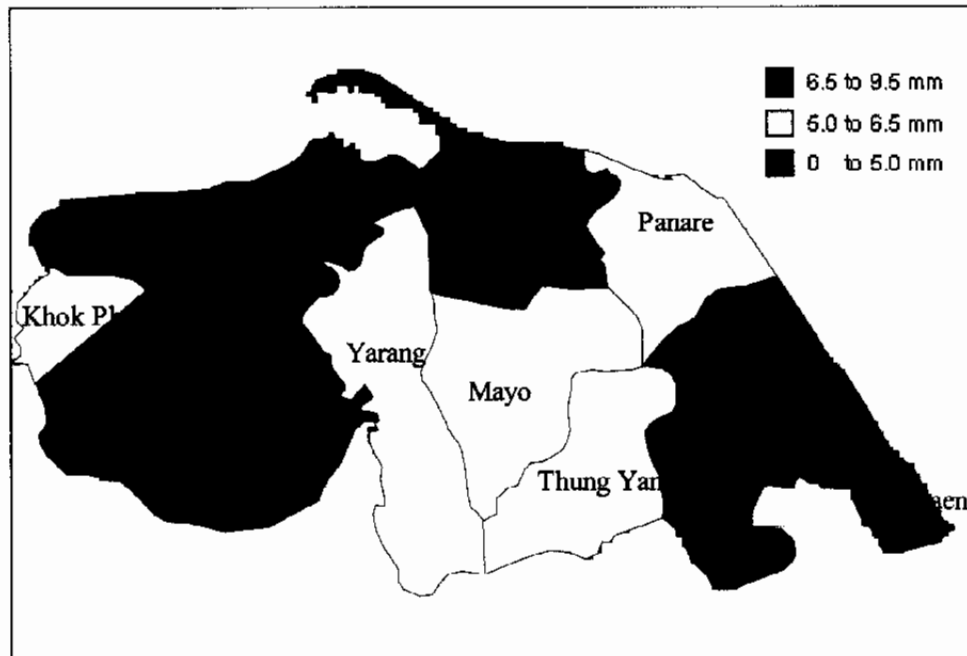


Figure 4.5: Range Map of ZAG Mean 5-day Rainfall in Pattani Province

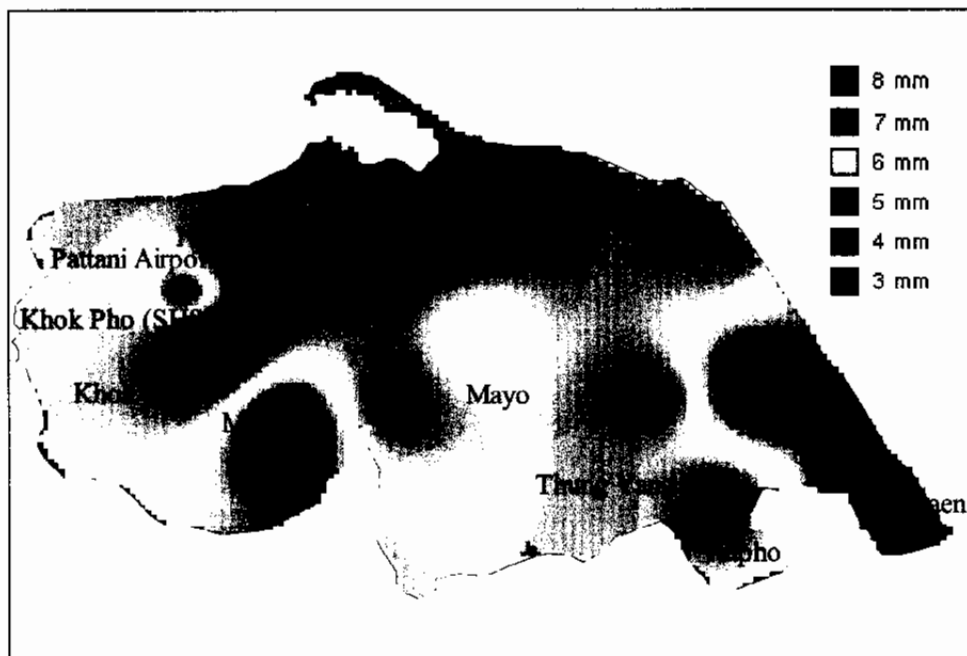


Figure 4.6: Grid Map of ZAG Mean 5-day Rainfall in Pattani Province

Figure 4.7 shows a contour map of the same data. In this case the ranges for the colour-coded regions between the contours are as follows.

Dark blue:	Less than 3.5 mm;
Light blue:	3.5 up to 4.5 mm;
Green:	4.5 up to 5.5 mm;
Yellow:	5.5 up to 6.5 mm;
Light Red:	6.5 up to 7.5 mm;
Dark red:	7.5 or greater.

As for Figure 4.4, these ranges are chosen to correspond to those used in the grid map.

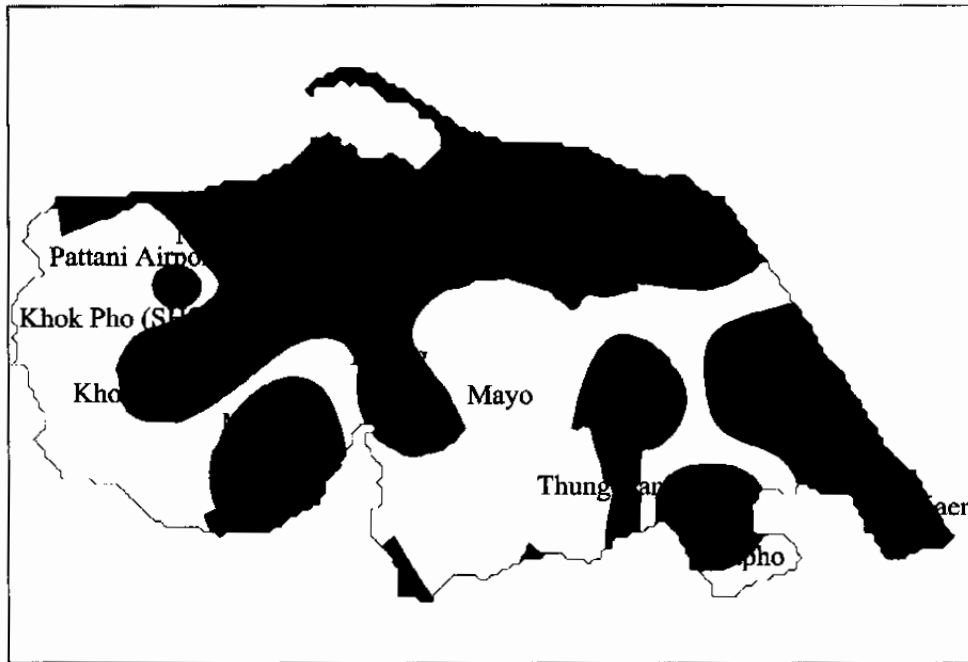


Figure 4.7: Contour Map of ZAG Mean 5-day Rainfall in Pattani Province

#### 4.2 Maps of Average 5-day Rainfall in the Rainy Season

Table 4.1 shows the zero-adjusted geometric means of the rainfall at the 14 stations in Pattani Province for the 10 successive periods from October 28-November 1 to December 12-16, the 50-day period where the rainfall is highest on average (the rainy season in south-eastern Thailand).

Figure 4.8 shows range maps of the data in Table 4.1, using the same six colours as in Figures 4.2-4.7, with ranges 0-9.9 mm, 10-19.9 mm, 20-29.9 mm, 30-39.9mm, 40-49.9 mm and 50+ mm, respectively.

<i>Station</i>	<i>5-day period</i>									
	61	62	63	64	65	66	67	68	69	70
Pattani	47.0	40.0	20.3	20.7	41.3	25.8	19.1	26.5	14.9	16.0
Sai Buri	56.8	43.0	29.3	30.4	85.5	44.1	46.1	55.5	34.0	30.3
Yarang	32.8	26.7	17.9	24.1	44.0	21.6	32.8	43.1	19.6	18.8
Khok Pho	15.1	26.1	7.5	12.3	22.7	15.6	18.3	10.4	12.5	7.7
Panare	44.2	39.8	36.6	33.0	49.5	29.8	40.6	47.5	21.3	31.0
Mayo	38.5	34.4	27.9	27.8	51.5	29.5	40.9	46.0	30.5	26.9
Ning Chik	44.6	46.3	17.3	23.1	58.4	37.5	44.4	47.0	16.2	19.0
Yaring	34.0	54.9	29.7	17.4	47.1	30.4	41.8	37.4	19.2	21.7
Kapho	24.6	29.0	27.6	34.6	37.6	25.8	38.1	79.2	32.3	30.9
Mai Kaen	57.4	62.9	26.2	57.5	77.6	57.0	56.4	66.9	46.7	37.7
Khok Pho(SHS)	40.8	25.4	20.3	19.5	34.6	20.2	22.3	31.6	22.9	15.1
ThungYangDang	19.7	29.4	19.9	35.5	74.7	15.4	15.8	36.8	20.3	8.9
Mae Lan	47.5	36.2	18.9	32.8	132.7	54.3	26.1	64.2	56.0	83.1
Pattani Airport	34.7	41.9	24.2	39.8	58.8	28.2	33.8	44.4	24.1	21.3

Table 4.1: Zero-adjusted Geometric Mean 5-day Rainfall over 1982-2000 from Period 61 (Oct 28-Nov 1) to Period 70 (Dec 12-16) in Pattani Province

Figures 4.9 show the grid maps, respectively, of the data from Table 4.1. Six colour bands were used, ranging from dark blue (0 mm), light blue (10 mm), green (20 mm), yellow (30 mm), orange (40 mm) and dark red (50 mm or greater).

Figures 4.10 show the contour maps, respectively, of the data from Table 4.1., using the same colour ranges as Figure 4.8.

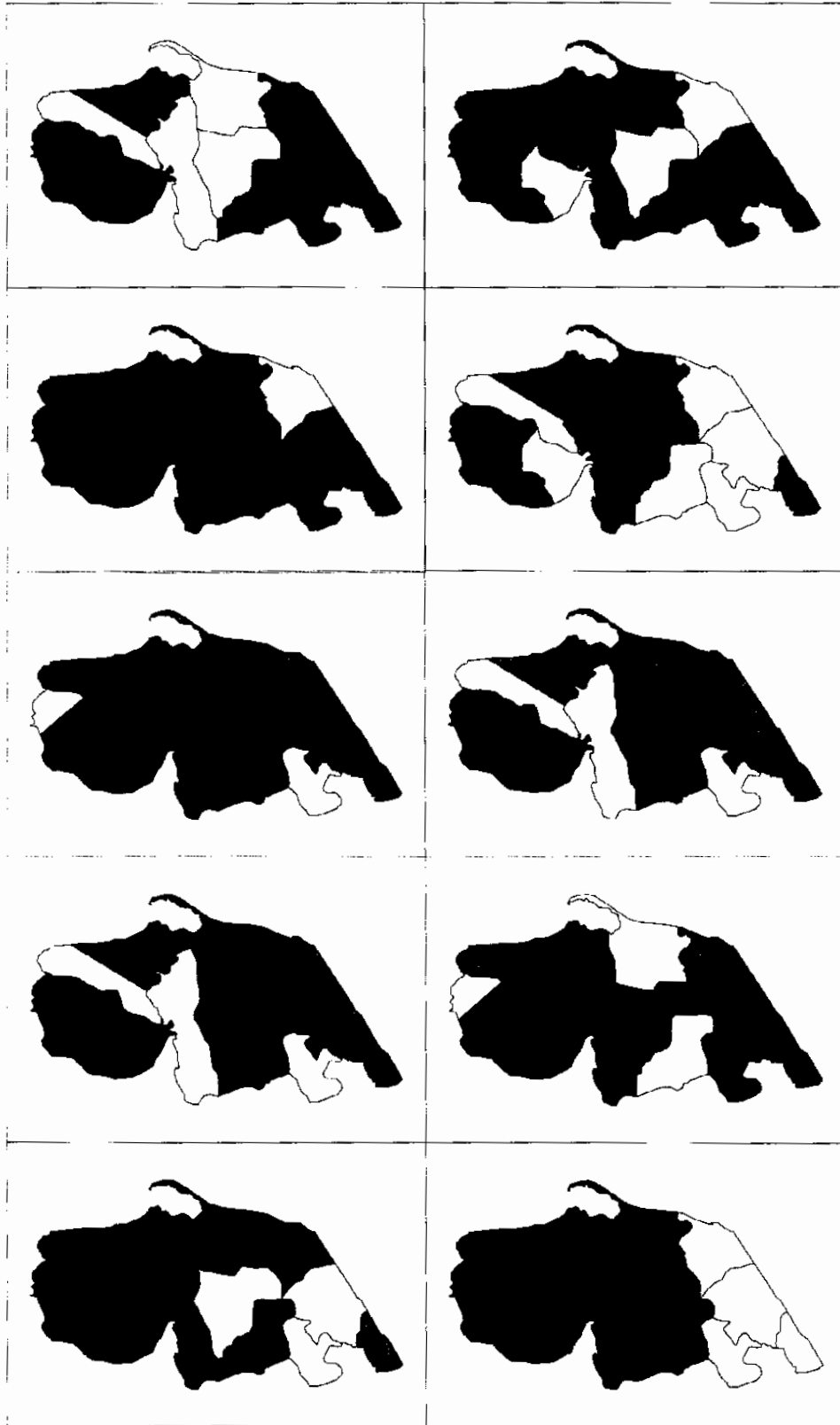


Figure 4.8: Range Maps of ZAG Mean 5-day Rainfall over 1982-2000 from Oct 28-  
Nov 1 to Dec 12-16 in Pattani Province



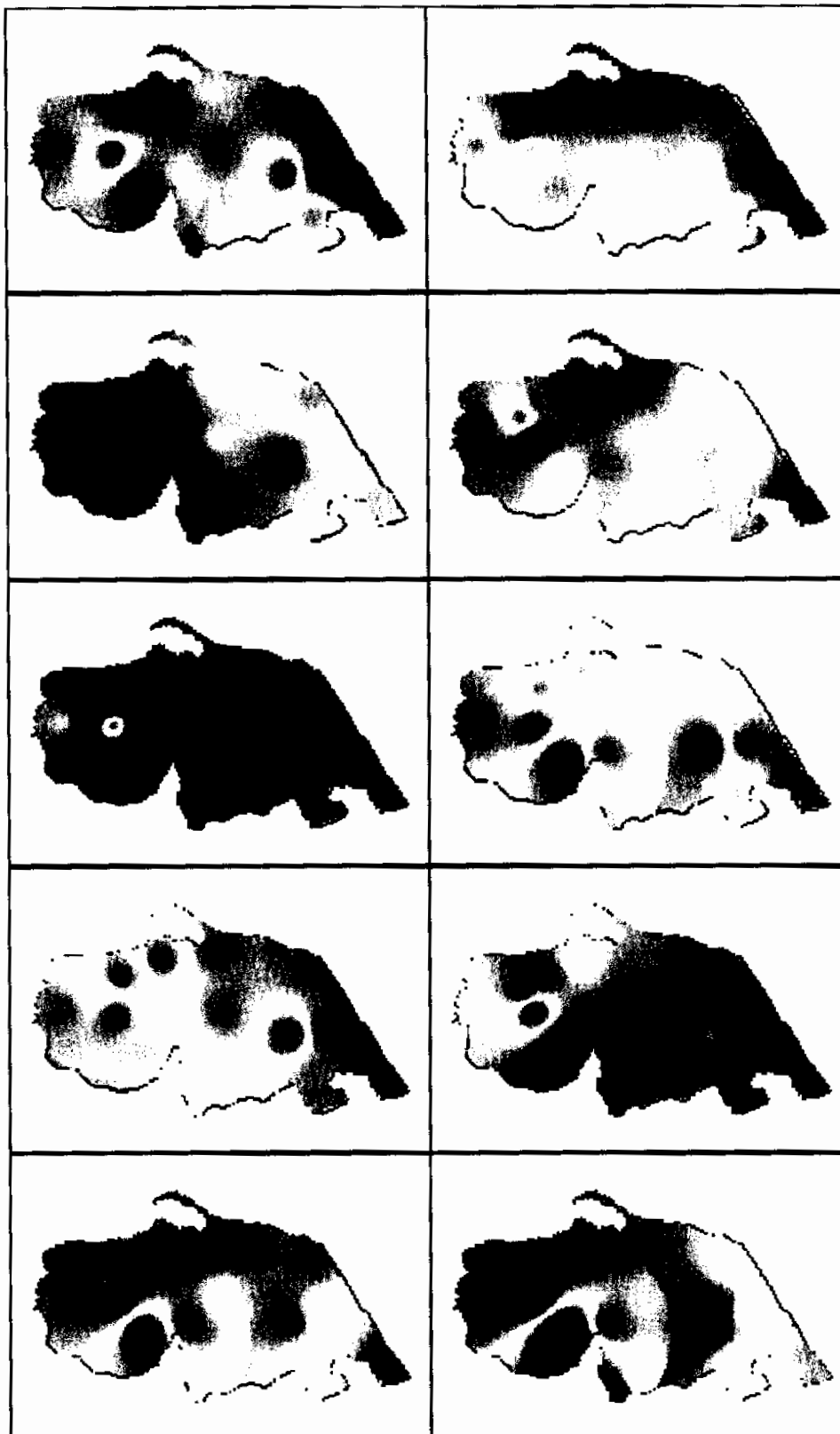


Figure 4.9: Grid Maps of ZAG Mean 5-day Rainfall over 1982-2000 from Oct 28-  
Nov 1 to Dec 12-16 in Pattani Province

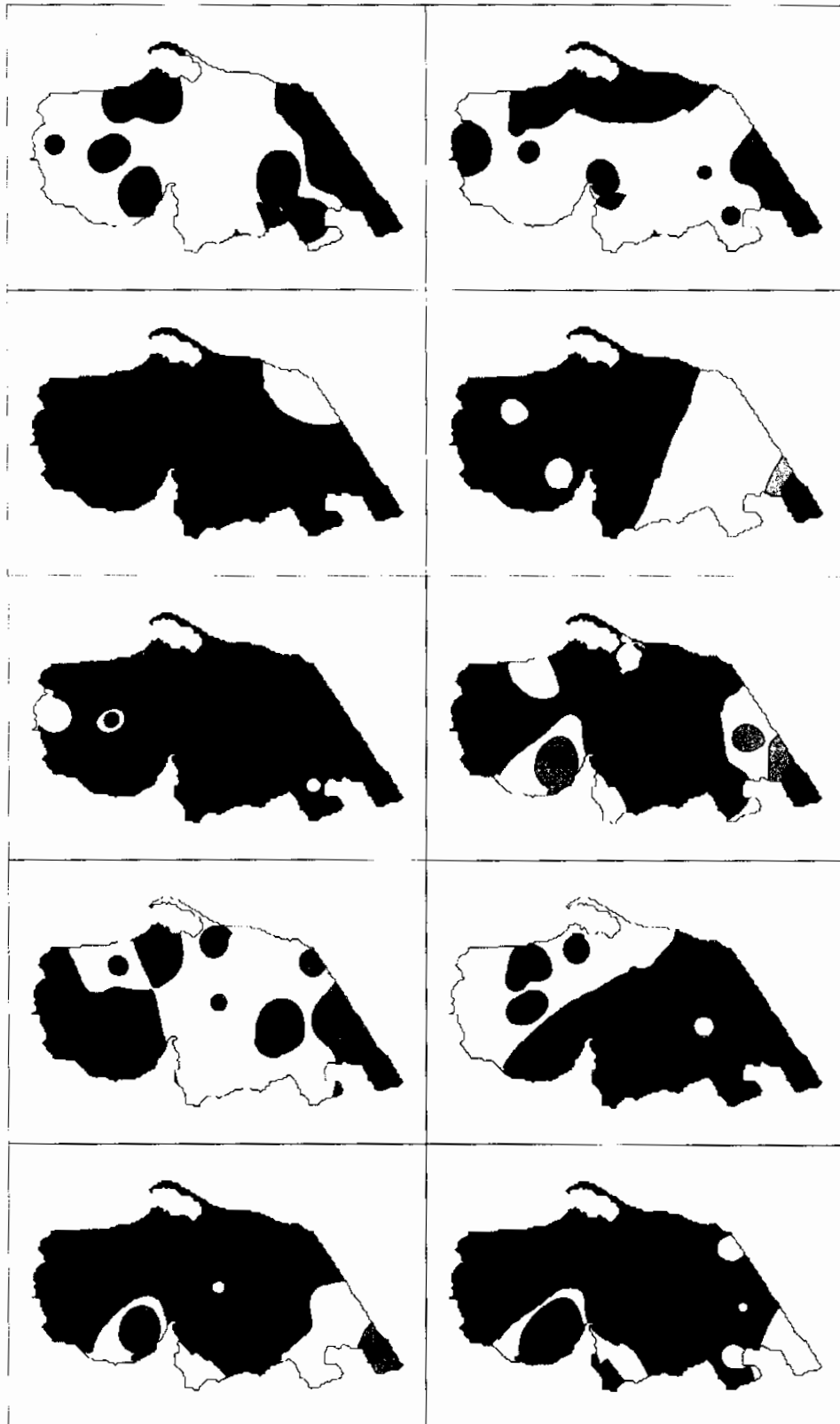


Figure 4.10: Contour Maps of ZAG Mean 5-day Rainfall over 1982-2000 from Oct 28-Nov 1 to Dec 12-16 in Pattani Province

<i>Station</i>	<i>5-day period</i>									
	61	62	63	64	65	66	67	68	69	70
Pattani	80.3	53.0	45.7	104.7	77.7	3.9	0.0	0.0	0.0	201.9
Sai Buri	182.5	85.7	55.5	102.2	63.2	2.5	26.4	11.1	0.0	267.0
Yarang	68.0	60.5	16.4	54.9	76.5	0.0	0.0	0.0	0.0	160.5
Khok Pho	81.5	122.3	0.0	132.7	132.9	0.0	10.1	0.0	0.0	231.5
Panare	24.6	121.9	72.4	86.2	79.9	0.0	4.4	0.0	0.0	269.7
Mayo	119.3	31.9	70.6	88.4	145.1	0.0	6.6	0.0	0.0	256.2
Ning Chik	70.5	35.1	12.6	123.0	52.0	6.7	0.0	0.0	0.0	180.1
Yaring	21.0	105.6	40.7	93.8	40.4	0.0	0.0	0.0	2.5	84.2
Kapho	112.0									
Mai Kaen	181.1	60.0	43.6	133.4	103.0	2.7	38.5	2.9	0.0	239.1
Khok Pho(SHS)	48.9	13.0	9.0	110.4	90.3	0.0	33.2	0.0	0.0	167.2
ThungYangDang	84.3	80.6	14.7	28.6	43.3	0.0	11.8	0.0	0.0	302.9
Mae Lan	99.4	67.2	20.5	39.6	75.4	0.0	15.9	0.0	0.0	208.4
Pattani Airport	90.9	41.1	21.2	112.8	98.8	2.4	0.7	3.9	0.0	177.3

Table 4.2: Observed 5-day Rainfall from Period 61 (Oct 28-Nov 1) to Period 70 (Dec 12-16) in Pattani Province in 2001

Table 4.2 shows the observed rainfall at the 14 stations in Pattani Province for the 10 successive periods from October 28-November 1 to December 12-16.

These data are mapped in Figures 4.11 (range maps), 4.12 (grid maps) and 4.13 (contour maps), respectively. The same colour scale is again used.

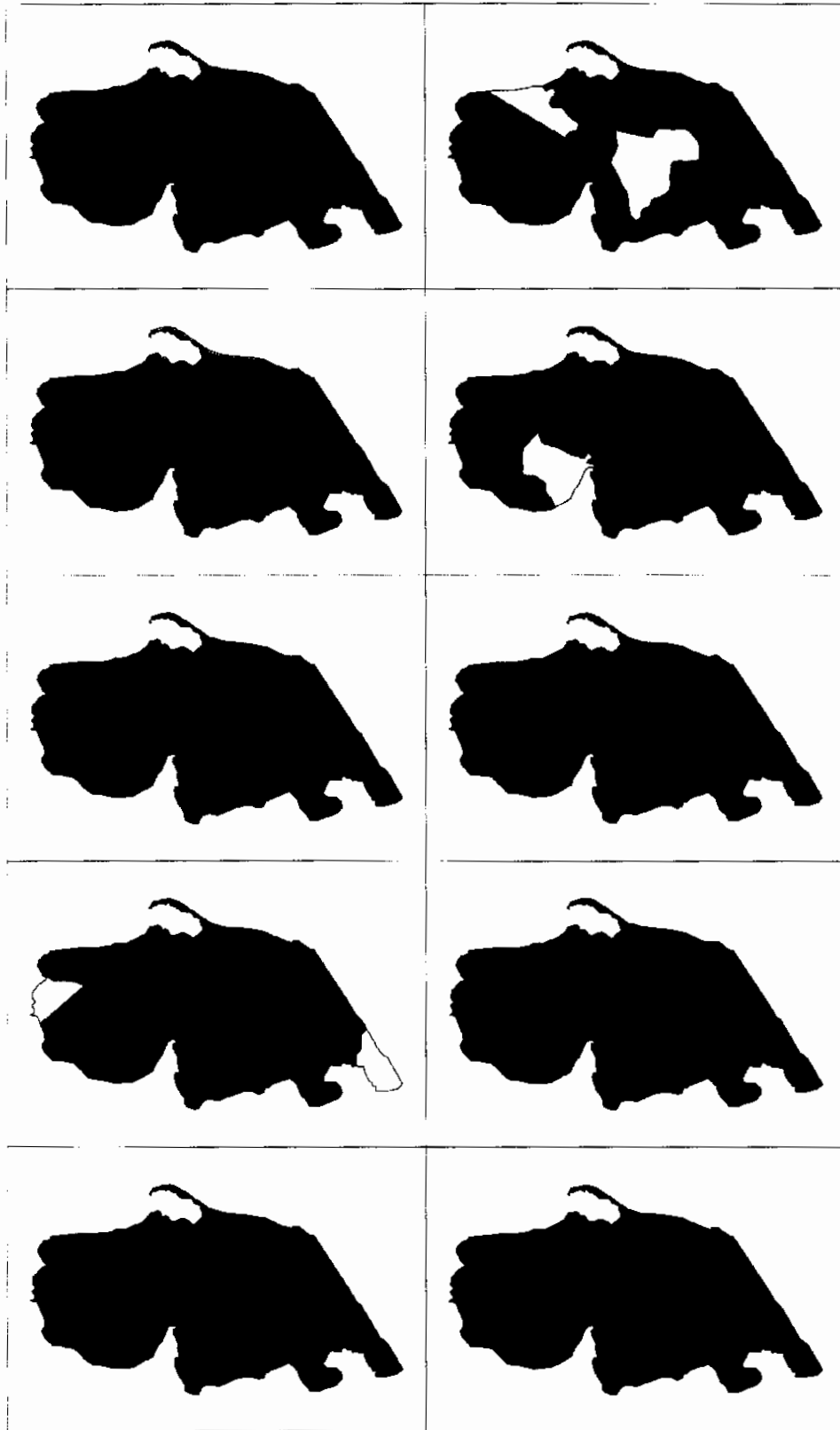


Figure 4.11: Range Maps of 5-day Rainfall from Oct 28-Nov 1 to Dec 12-16, 2001 in Pattani Province

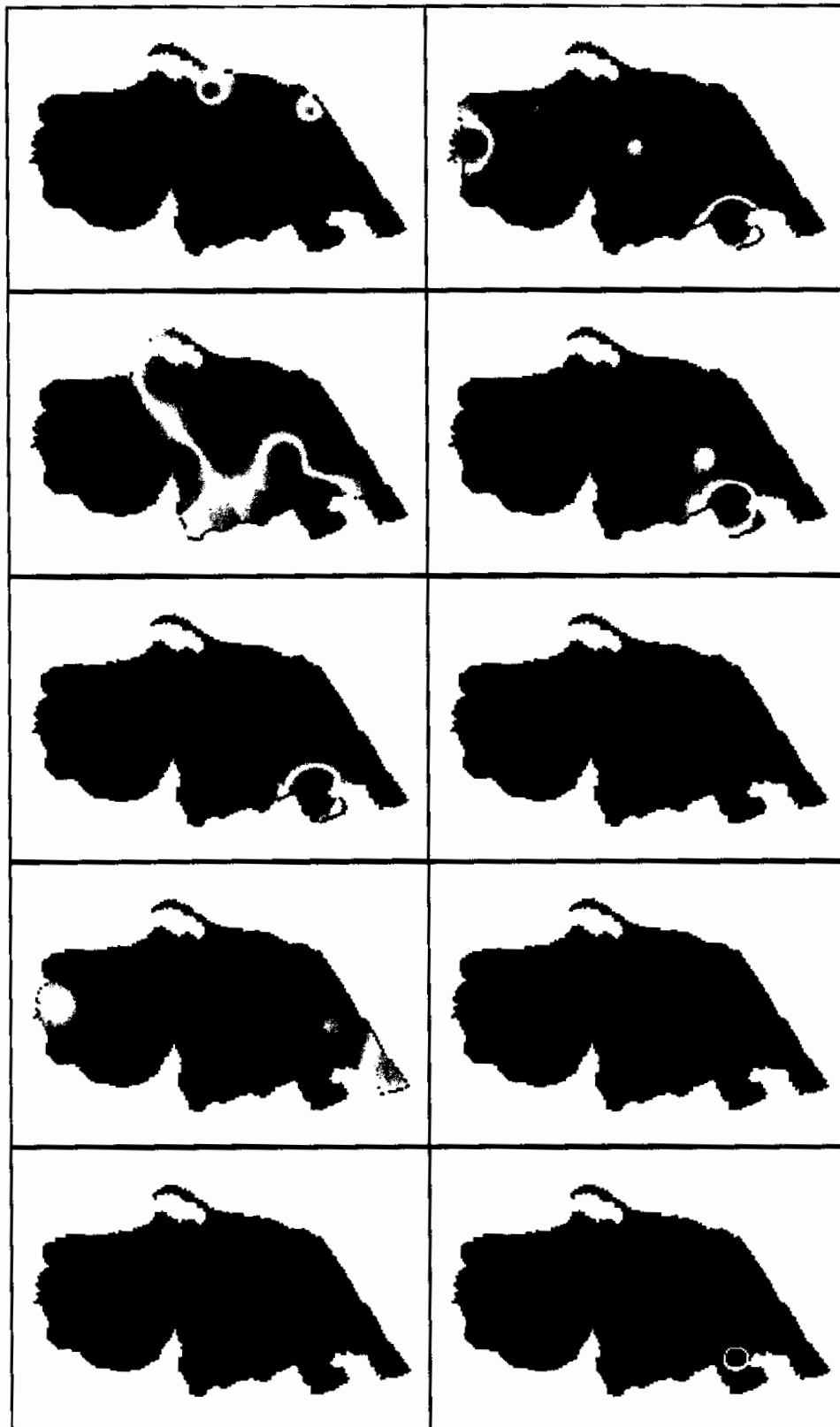


Figure 4.12: Grid Maps of Observed 5-day Rainfall from Oct 28-Nov 1 to Dec 12-16 in Pattani Province in 2001

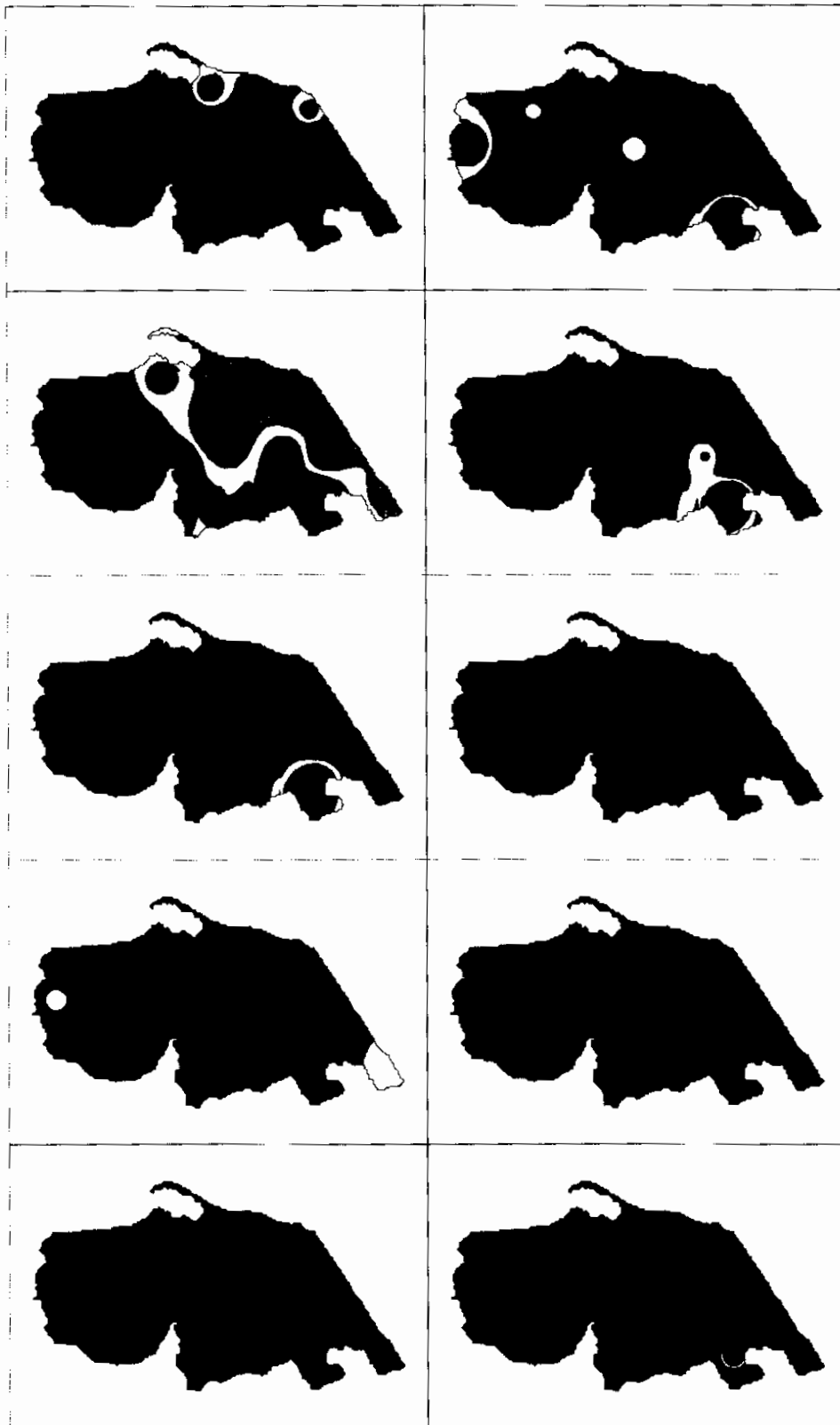


Figure 4.13: Contour Maps of Observed 5-day Rainfall from Oct 28-Nov 1 to Dec 12-16 in Pattani Province in 2001

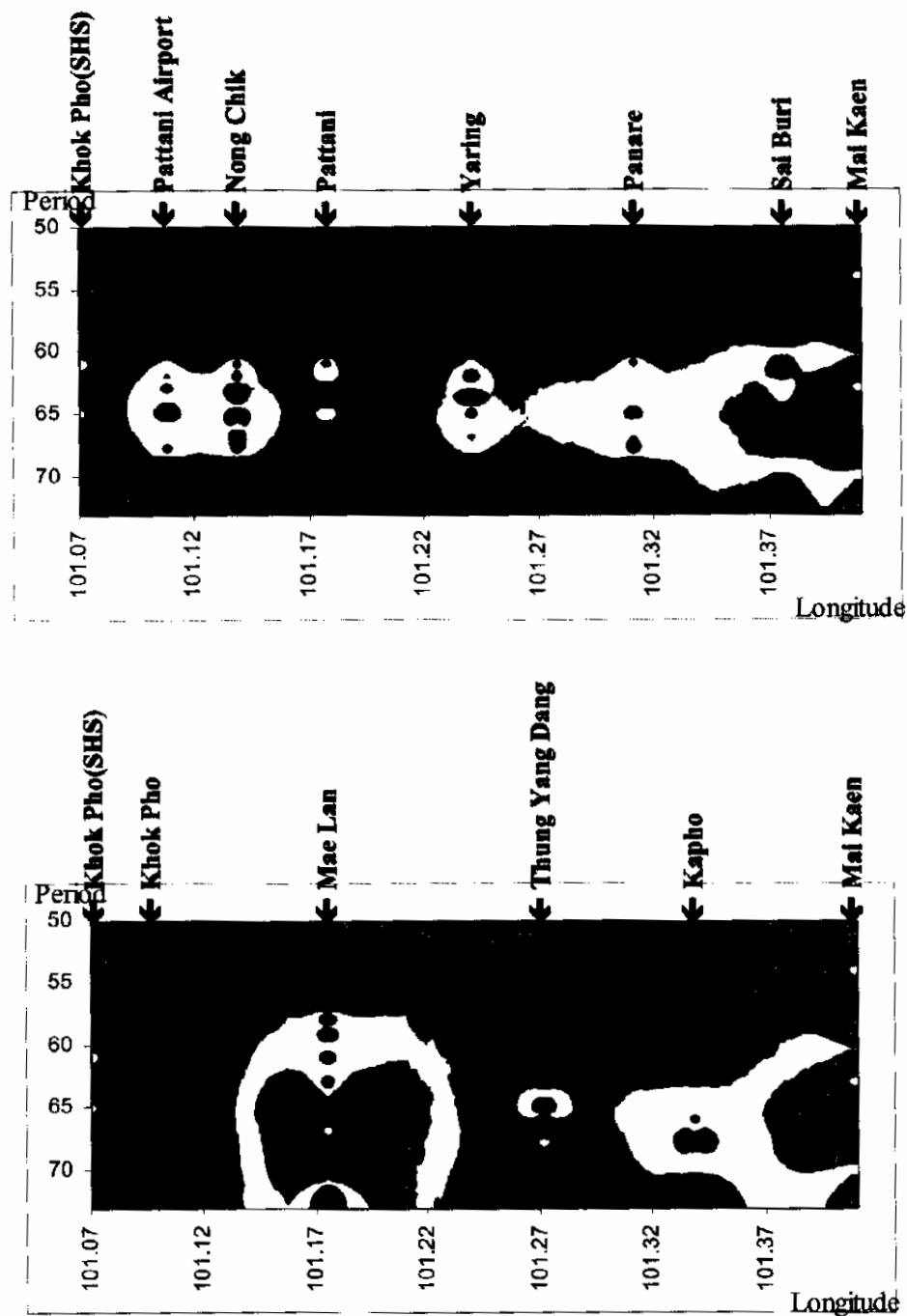


Figure 4.14: Contour Map of ZAG Mean 5-day From Sep 3-7 to Dec 27-31

Figure 4.14 shows two cross-sections of a three-dimensional contour map of the average rainfall data during the rainy season (September to December inclusive). The vertical axis denotes the period, whereas the horizontal axis refers to the longitude, so the cross-section taken has approximately constant latitude. The upper panel shows the data from the northernmost eight stations - Khok Pho (SHS), Pattani Airport,

Nong Chik, Pattani, Yaring, Panare, Sai Buri and Mai Kaen. Similarly, the lower panel shows the data from 6 stations - Khok Pho (SHS), Khok Pho, Mae Lan, Thung Yang Dang, Kapo and Mai Kaen. The same colour ranges as in Figure 4.10 are used. Note that the stations with the extreme longitudes (Khok Pho on the west and Mai Kaen on the east) are depicted in both panels, whereas the two central stations (Yarang and Mayo) are not shown in either panel.

The graph shows how the rainfall first increases and then declines during the rainy season, and also shows that the highest rainfall occurred at Mae Lan and Mai Kaen.