Chapter III

Simulation of Circulation Patterns

1. Initial and boundary conditions, and computational input

For input of hydrodynamic model, the averaged depth from the navigation chart, and the 8-year averaged wind field, including the water elevation at the open boundary were used as input to compute the water circulation in the Gulf of Thailand.

For initial and boundary conditions, the model was taken initially at rest, the no-motion condition. Along the solid coastal boundary, the normal component of volume transport is specified as zero. At the open grid element, linearly interpolated water elevation from Kampong Som in Cambodia to Kuala Trengganu in Malaysia was read. The water at both points were calculated by harmonic analysis using four predominant tidal constituents namely K1, O1, M2 and S2, reported by Choi, Kim, and Kim (1996). These coefficients are shown in table 1.

The original wind data over the South China Sea from the European Center for Medium range Weather Forecast (ECMWF) were used in the surface stress terms. The data stored every 1×1 degree grid spacing for every 6 hours time step from January 1, 1980 to July 31, 1988 were averaged in time. First, the data at the same time step but different year were summed and averaged. The result of this processing, 8-year averaged data, were linearly interpolated in space and time to fit the grid spacing and time step of hydrodynamic model. In this process, for space interpolation, the 1×1 degree grid spacing data were interpolated to 6×6 minutes, and for time interpolation the data at every 6 hours time step were interpolated to half an hour time step. The monthly averaged wind data at every grid point over the Gulf of Thailand were shown in the form of vector field plotting in figure 4 to15.

Table 1. Tidal constituents at Campong Som and Kuala Trengganu (Choi et al., 1996)

Tidal Constituents	At the upper point (Campomg Som)		At the lower point (Kuala Trengganu)	
	Amp. (cm)	Phase (degree)	Amp. (cm)	Phase (degree)
K1	22.7	195.2	48.2	66.0
O1	15.9	150.6	26.7	11.9
M2	13.7	5.3	29.4	207.5
S2	9.1	111.0	11.3	284.6

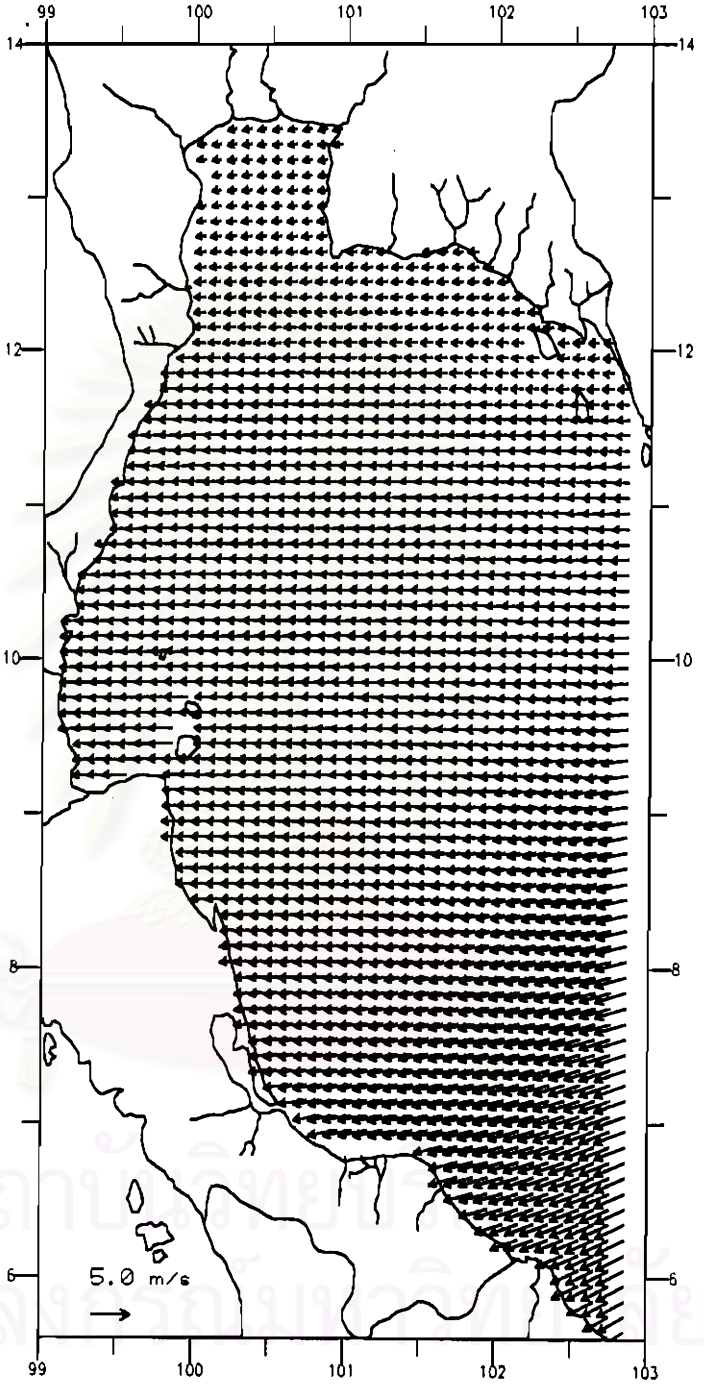


Figure 4. Monthly mean wind field in January

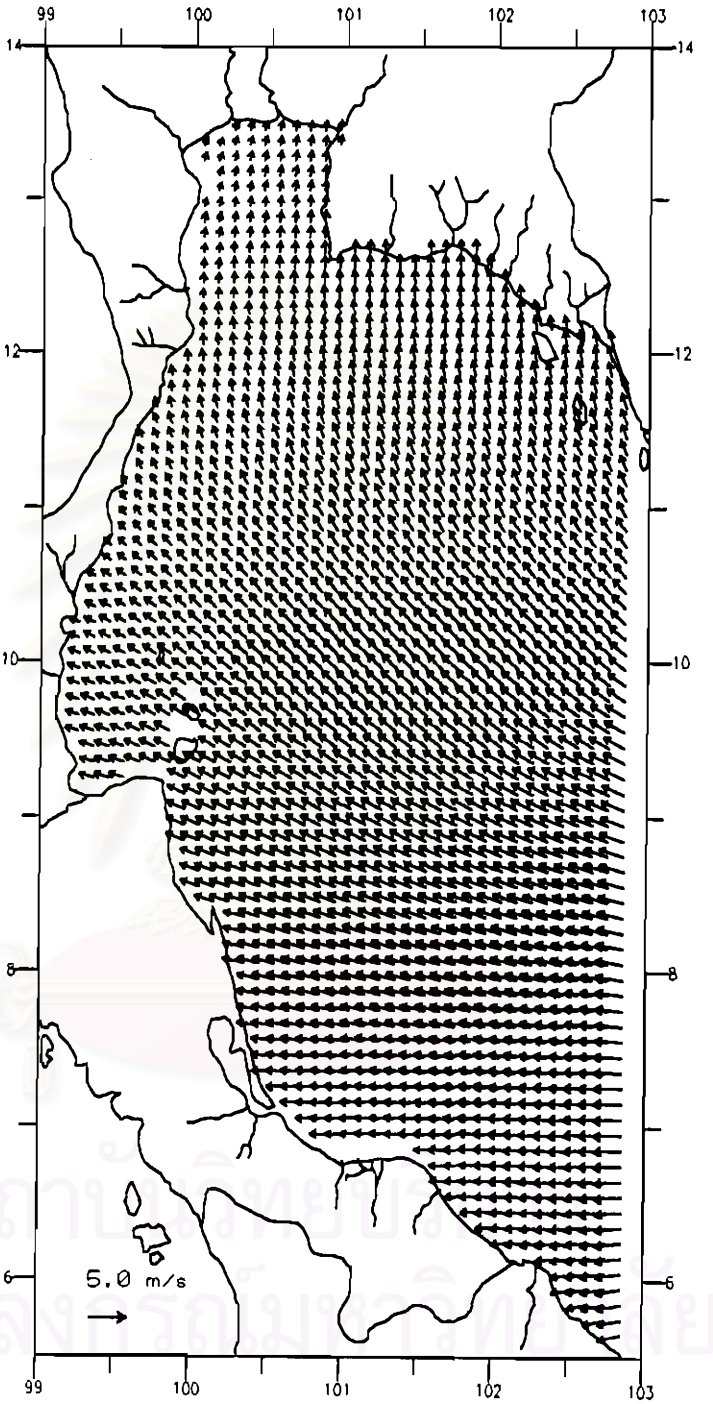


Figure 5. Monthly mean wind field in February

Figure 6. Monthly mean wind field in March.

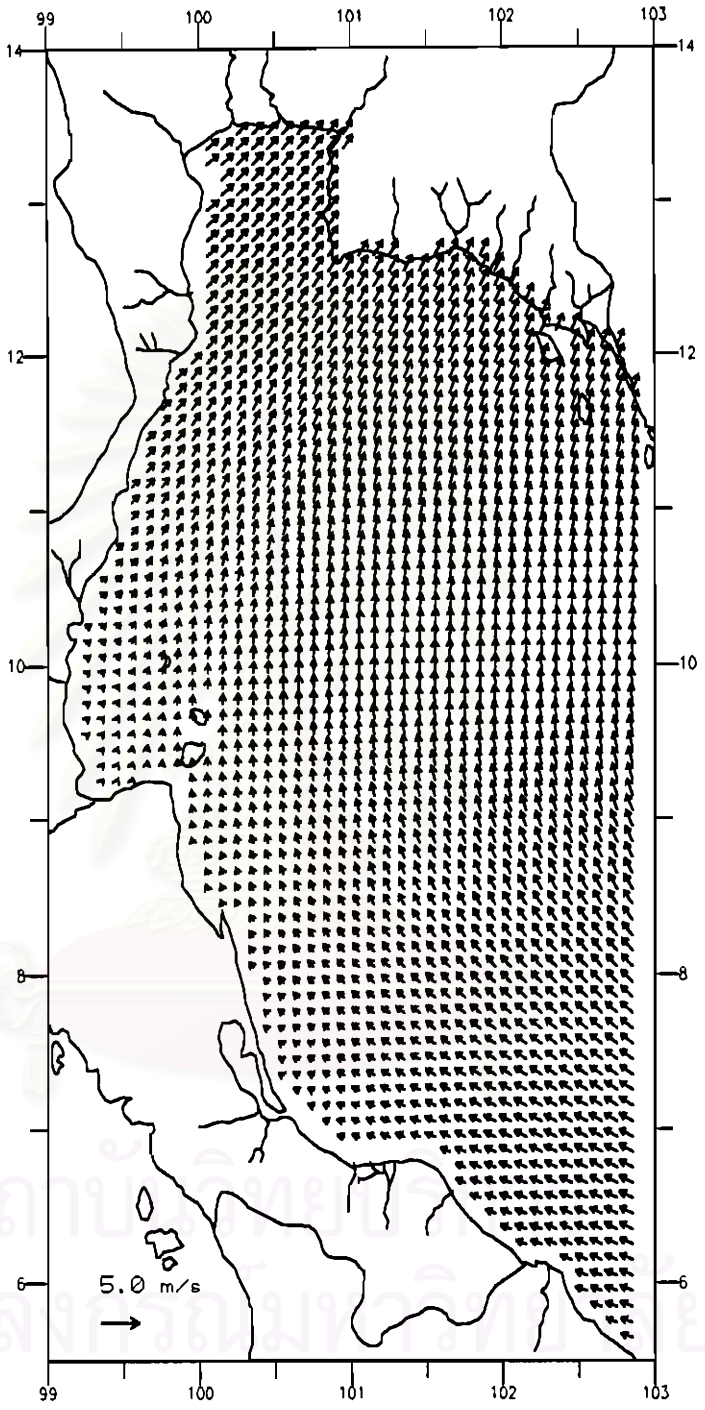


Figure 7. Monthly mean wind field in April.

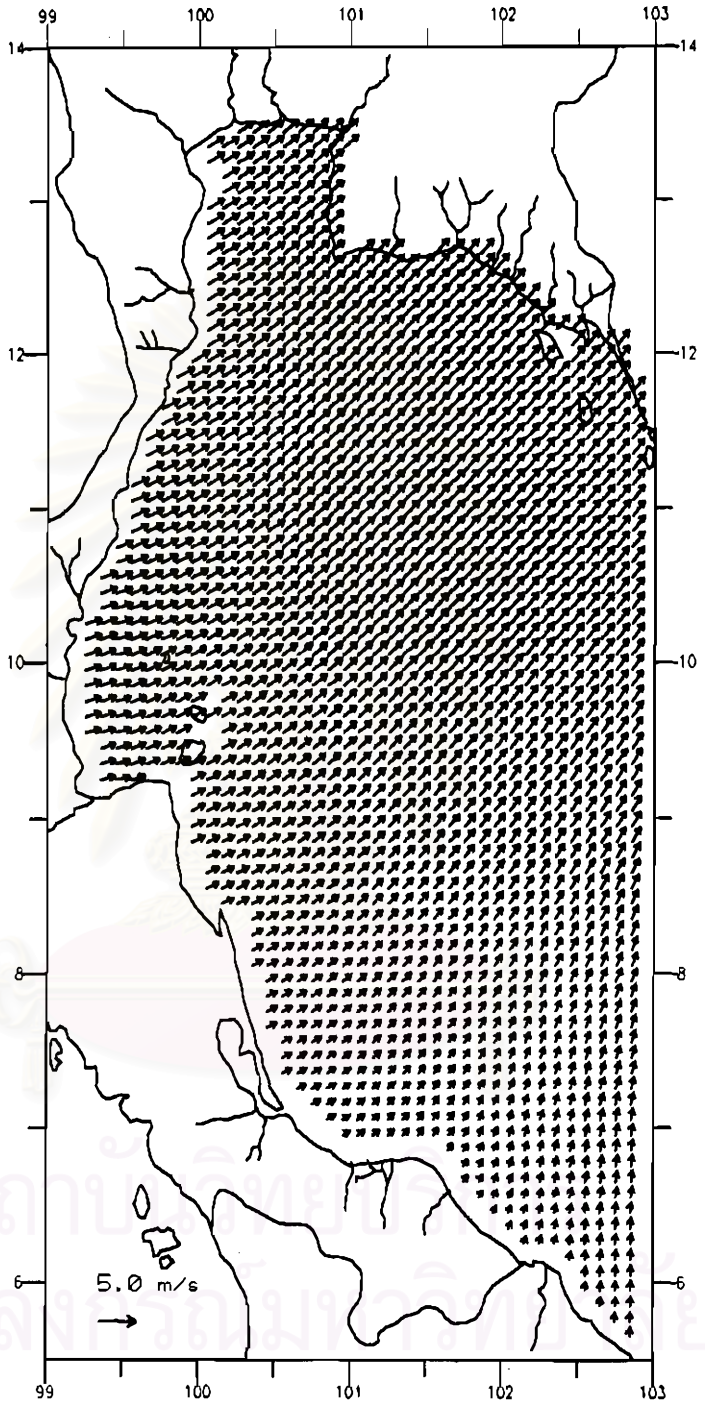


Figure 8. Monthly mean wind field in May.

Figure 9. Monthly mean wind field in June.

Figure 10. Monthly mean wind field in July

Figure 11. Monthly mean wind field in August.

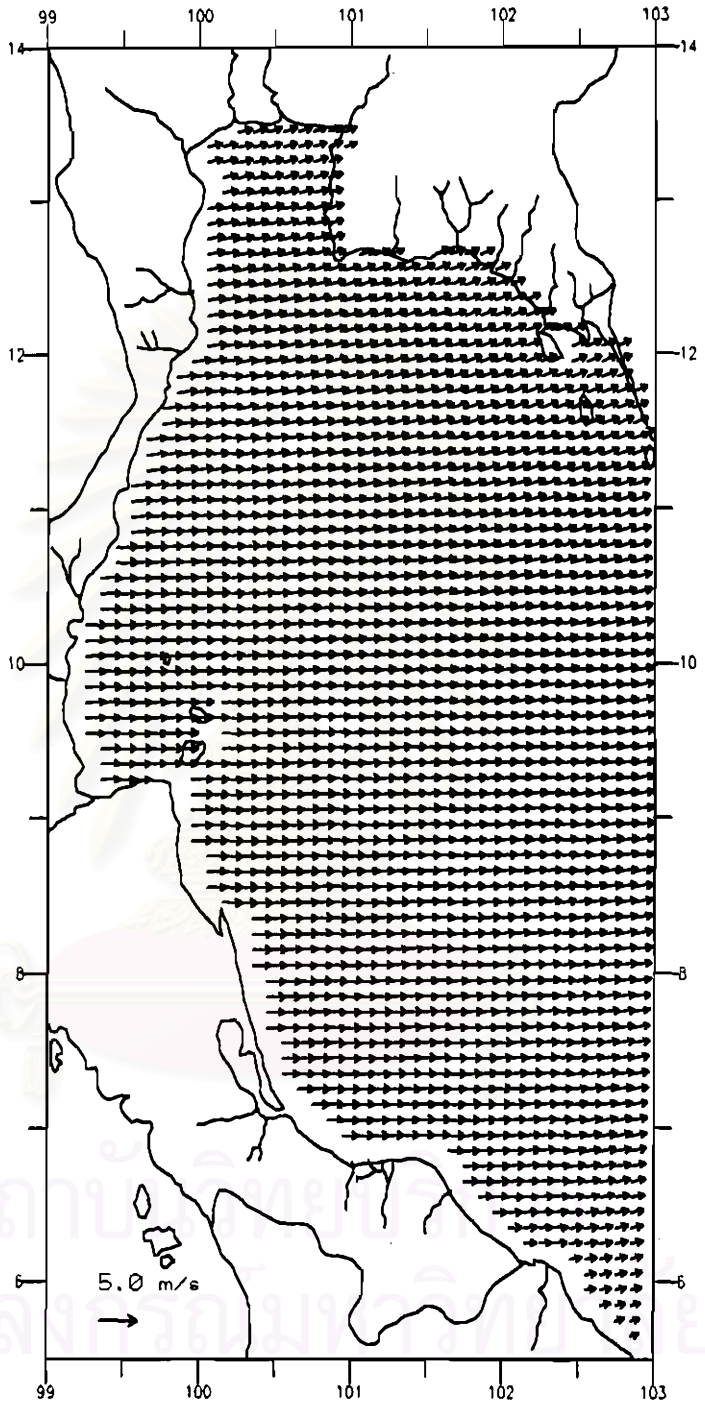


Figure 12. Monthly mean wind field in September

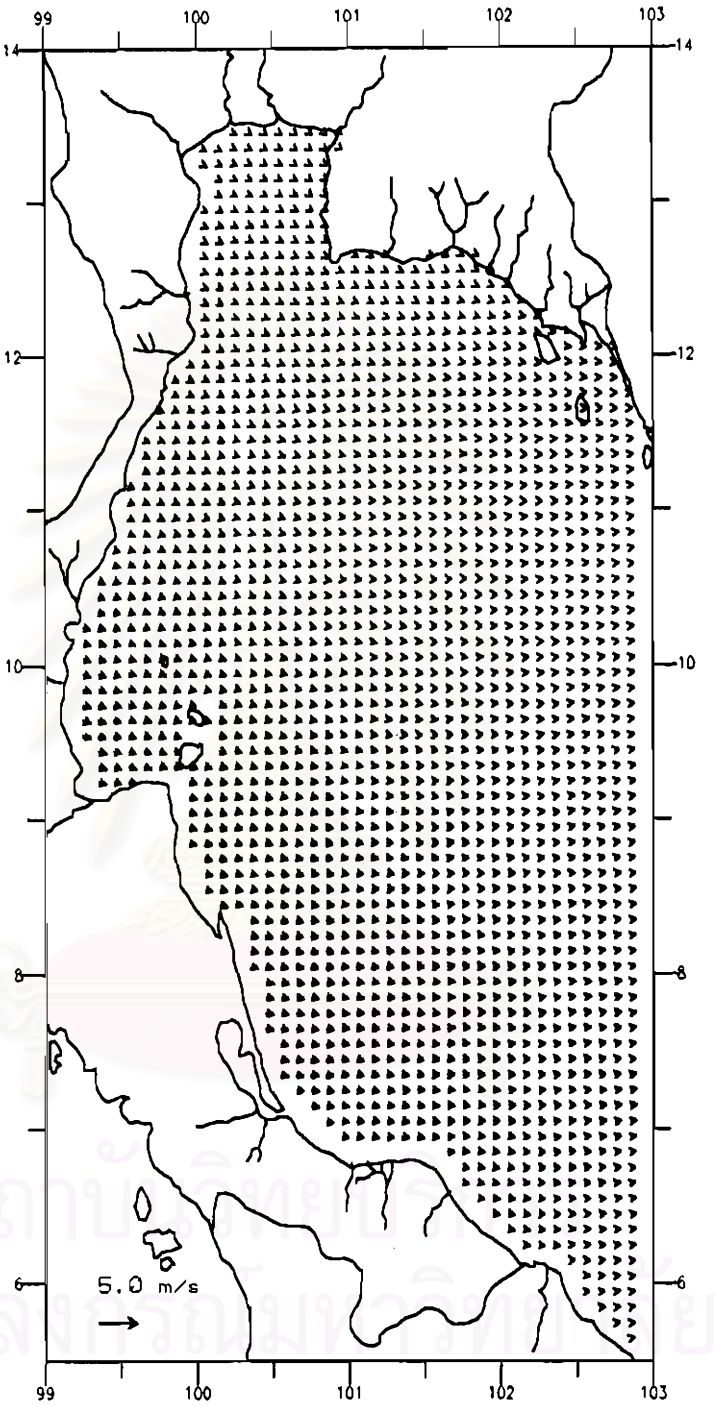


Figure 13. Monthly mean wind field in October

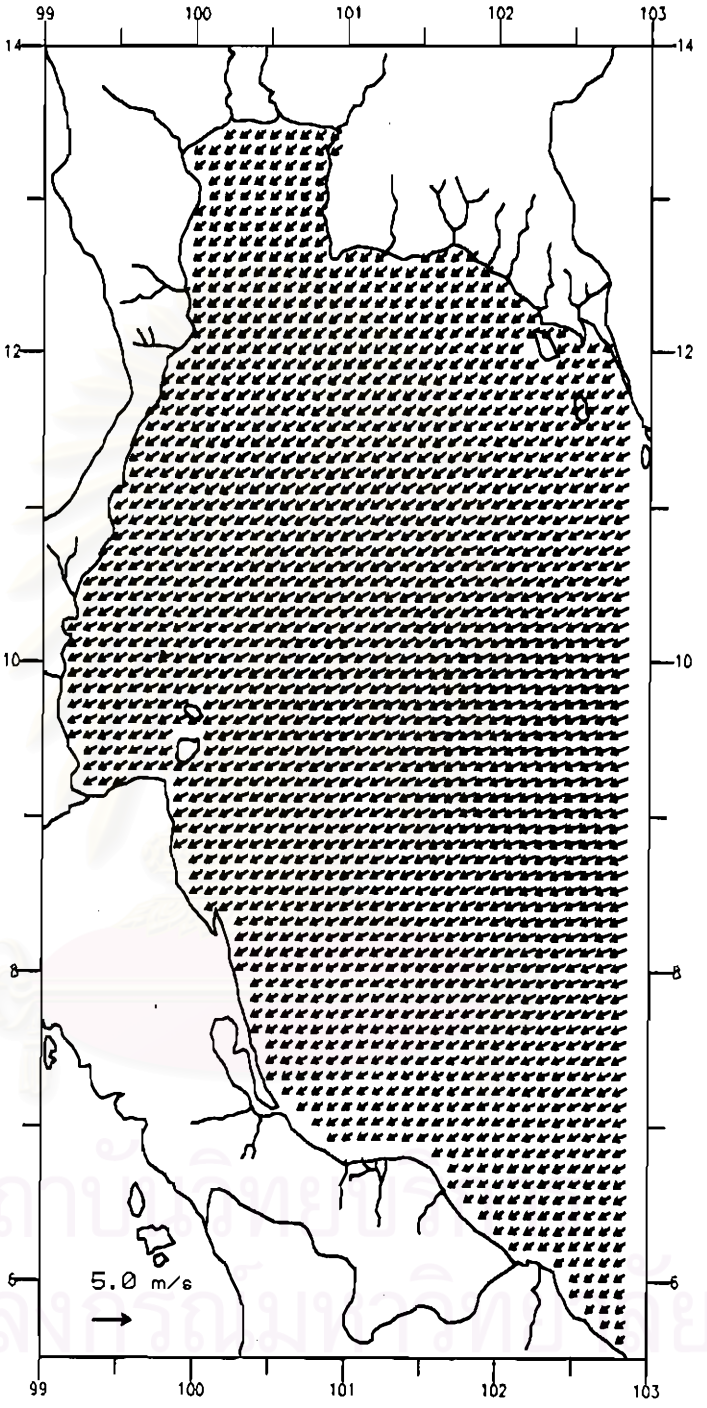


Figure 14. Monthly mean wind field in November.

Figure 15. Monthly mean wind field in December

2. Hydrodynamic model verification

The computational current generated by the hydrodynamic model in every month of the year 1994 were compared to the measured current data from oceanographic buoys deployed by National Research Council of Thailand (NRCT). There were 9 stations of oceanographic buoys in the Gulf of Thailand, namely Ko Chang, Rayong, Ko Sichang, Petchaburi, Hua Hin, Ko Tao, Nakorn Srithammarat, Songkla, and Platong. The geographic positions of these buoys were shown in table 2 and figure 16. However, available data could not be used wholly of these stations, because of the problem of buoys operation. A list of stations that could be used for verification was presented in table 3.

For verification, the current data from model at the same position of oceanographic buoys were compared in the form of time series. To depict the pattern of tidal cycle, the scale of time had to be long enough to see it, therefore the 15 days time scale was selected. The fluctuation between spring and neap tide can be observed in most of the charts. The comparison was shown in figure 17 to 61. In each figure, the magnitude and direction of current were separately plotted. Dash line illustrated the measured current while solid line showed computed current by hydrodynamic model.

Table 2. The geographical positions of oceanographic buoys in the Gulf of Thailand

Stations	Position	
	Latitude	Longitude
Ko Chang	12° 00'	102° 12'
Rayong	12° 30'	101° 13'
Ko Sichang	13° 15'	100° 45'
Petchaburi	13°04'	100°19'
Hua Hin	12° 30'	100° 10'
Ko Tao	10° 34'	99° 50'
Nakorn Srithammarat	08°44'	100°13,
Songkla	07° 30'	101° 13'
Platong	09° 42'	101° 26'

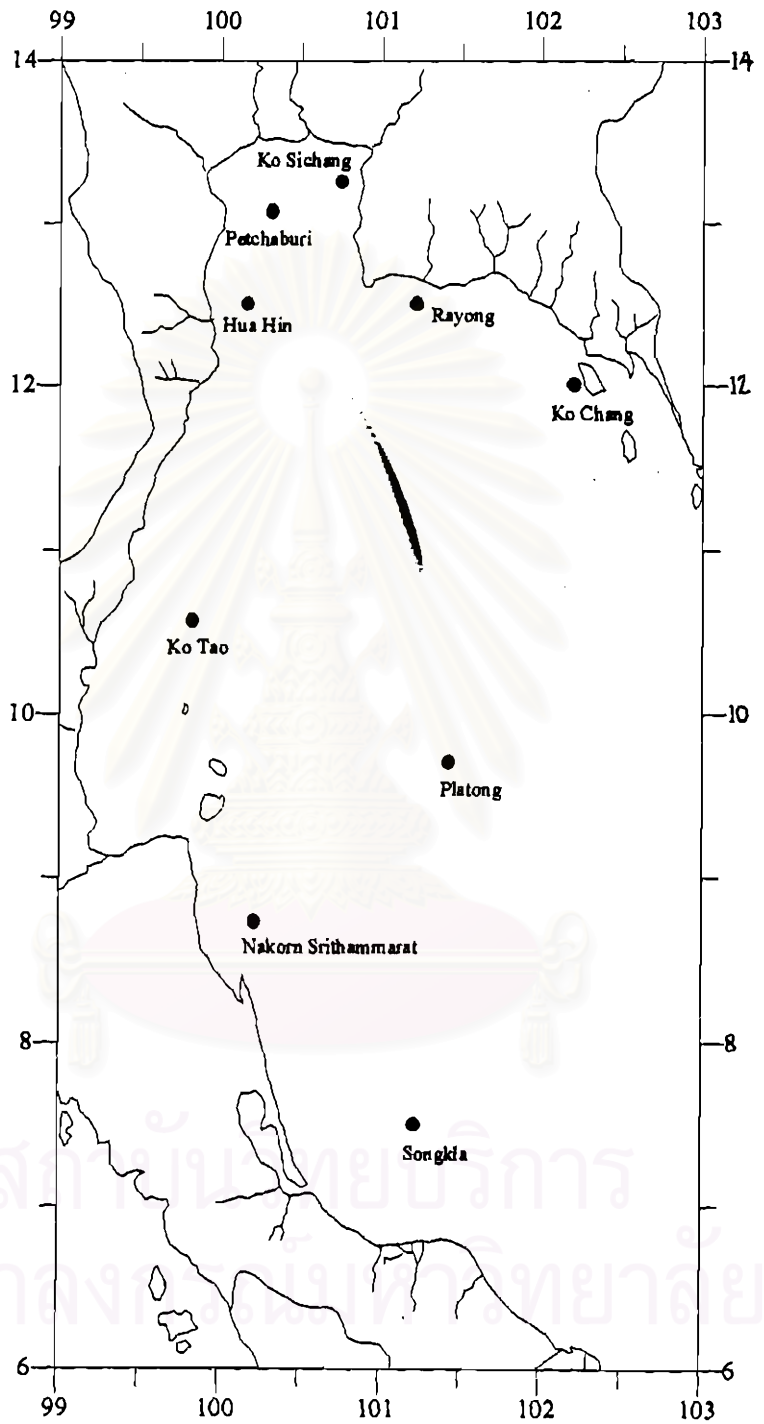


Figure 16. The positions of oceanographic buoys deployed in the Gulf of Thailand

Table 3. The list of available oceanographic buoys data in each month that can be used for hydrodynamic model verification in 1997.

Months	Stations								
	Chang	Rayong	Sichang	Petchaburi	Hua Hin	Tao	Nakorn	Songkla	Platong
January	-	/	-	-	-	-	-	-	-
February	/	/	/	-	/	-	-	-	-
March	/	/	/	/	/	-	-	-	-
April	/	/	/	/	/	-	-	-	-
May	-	/	-	/	/	-	-	-	-
June	/	/	/	/	/	-	-	-	-
July	/	/	/	-	-	-	-	-	-
August	/	/	/	-	-	-	-	-	-
September	/	/	/	-	/	-	-	-	-
October	/	/	-	-	/	-	-	-	-
November	/	/	-	-	/	-	-	-	-
December	/	/	/	/	-	/	/	-	-

Remarks : / referred to available data

- referred to unavailable data.

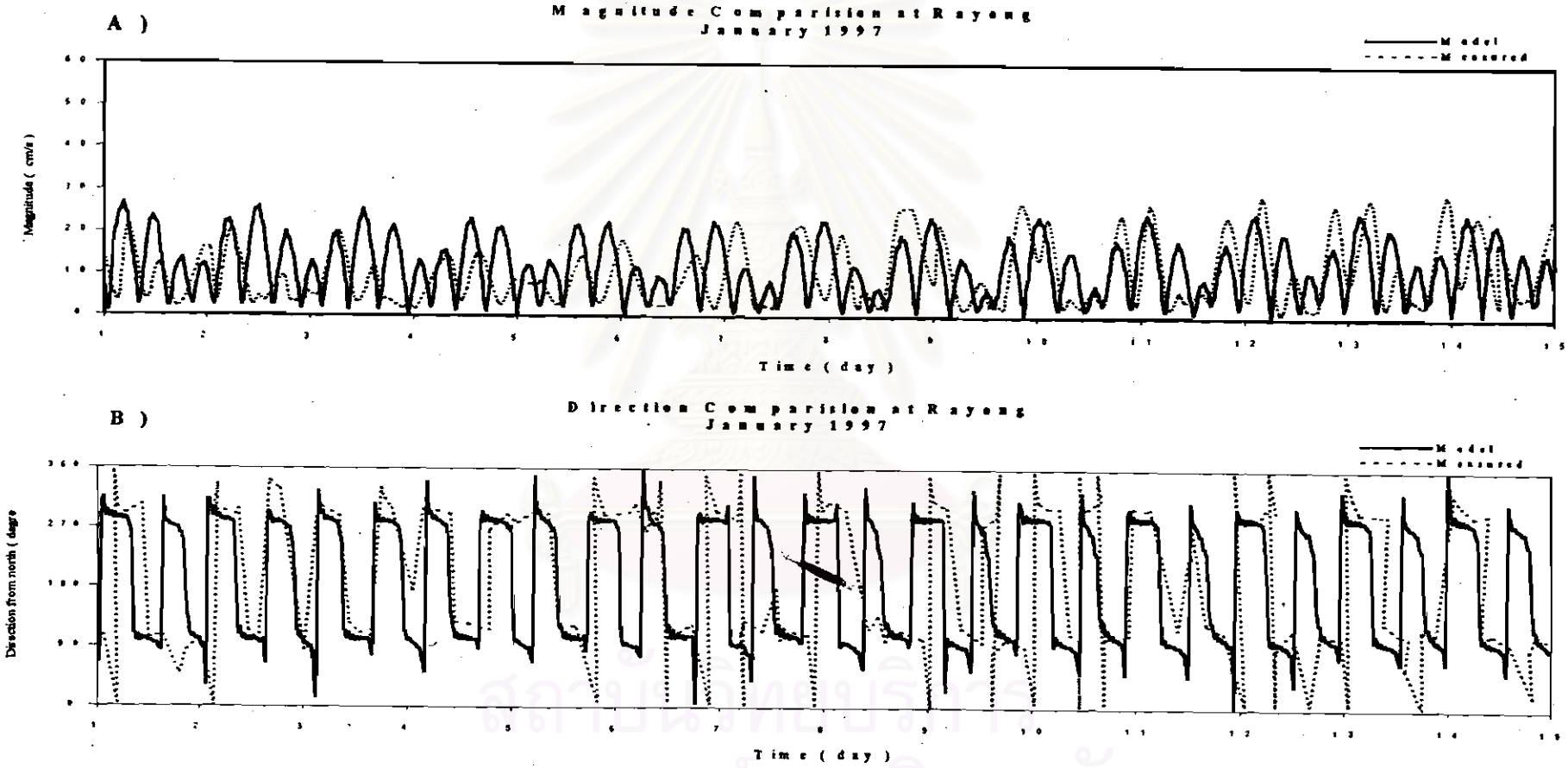


Figure 17. Comparison of measured and computed current at Rayong in January 1997

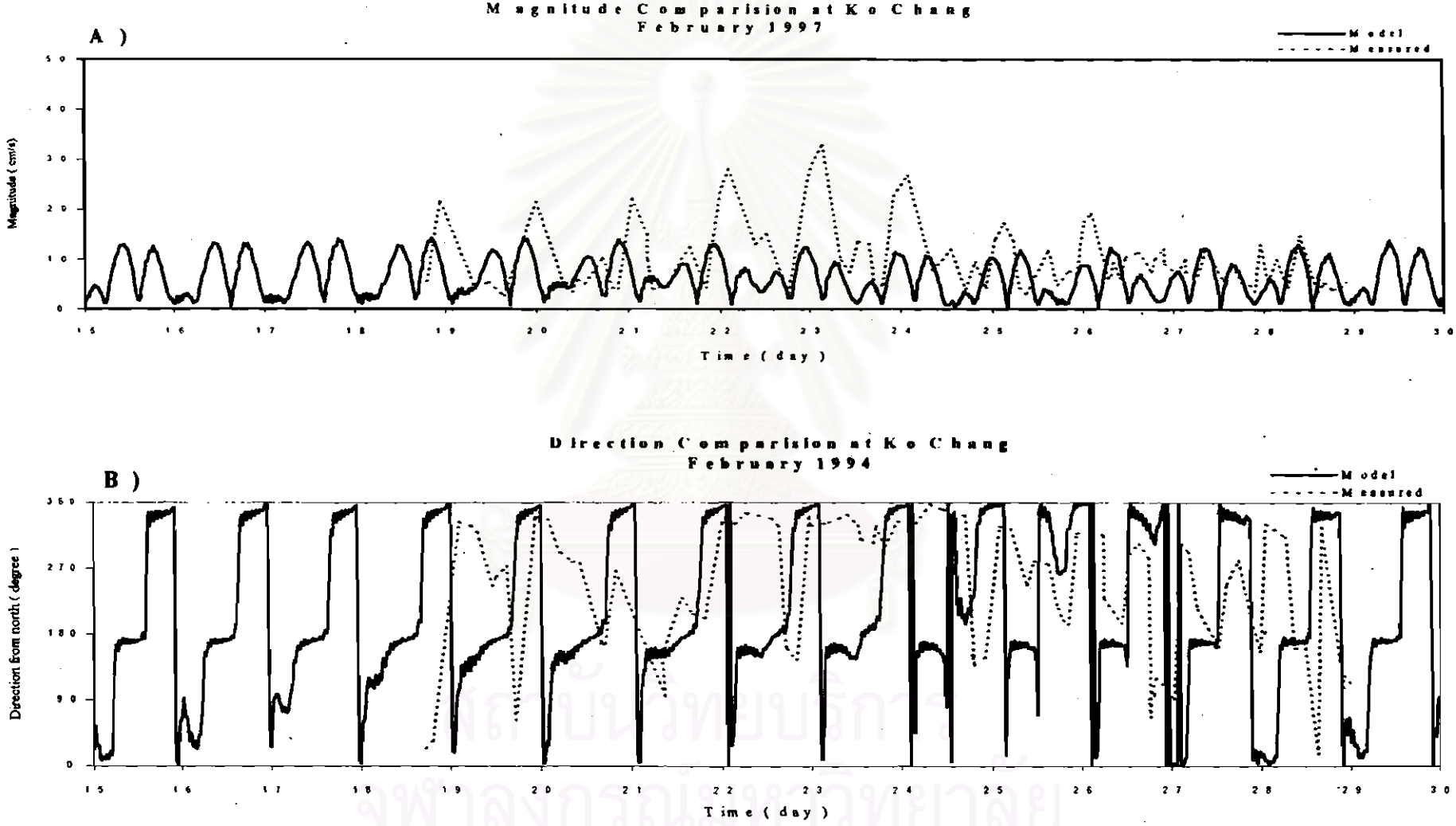


Figure 18. Comparison of measured and computed current at Ko Chang in February 1997

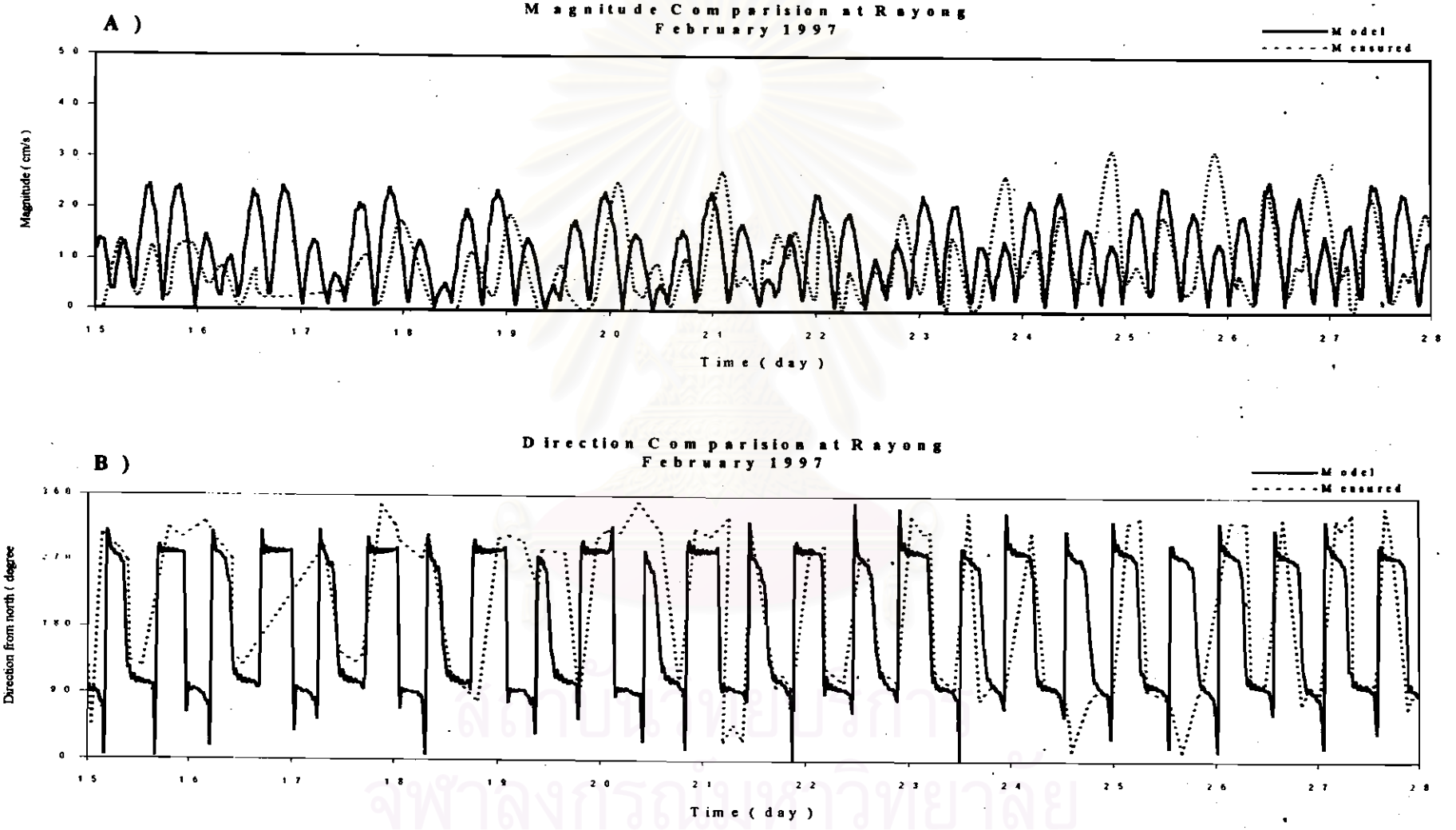


Figure 19. Comparison of measured and computed current at Rayong in February 1997

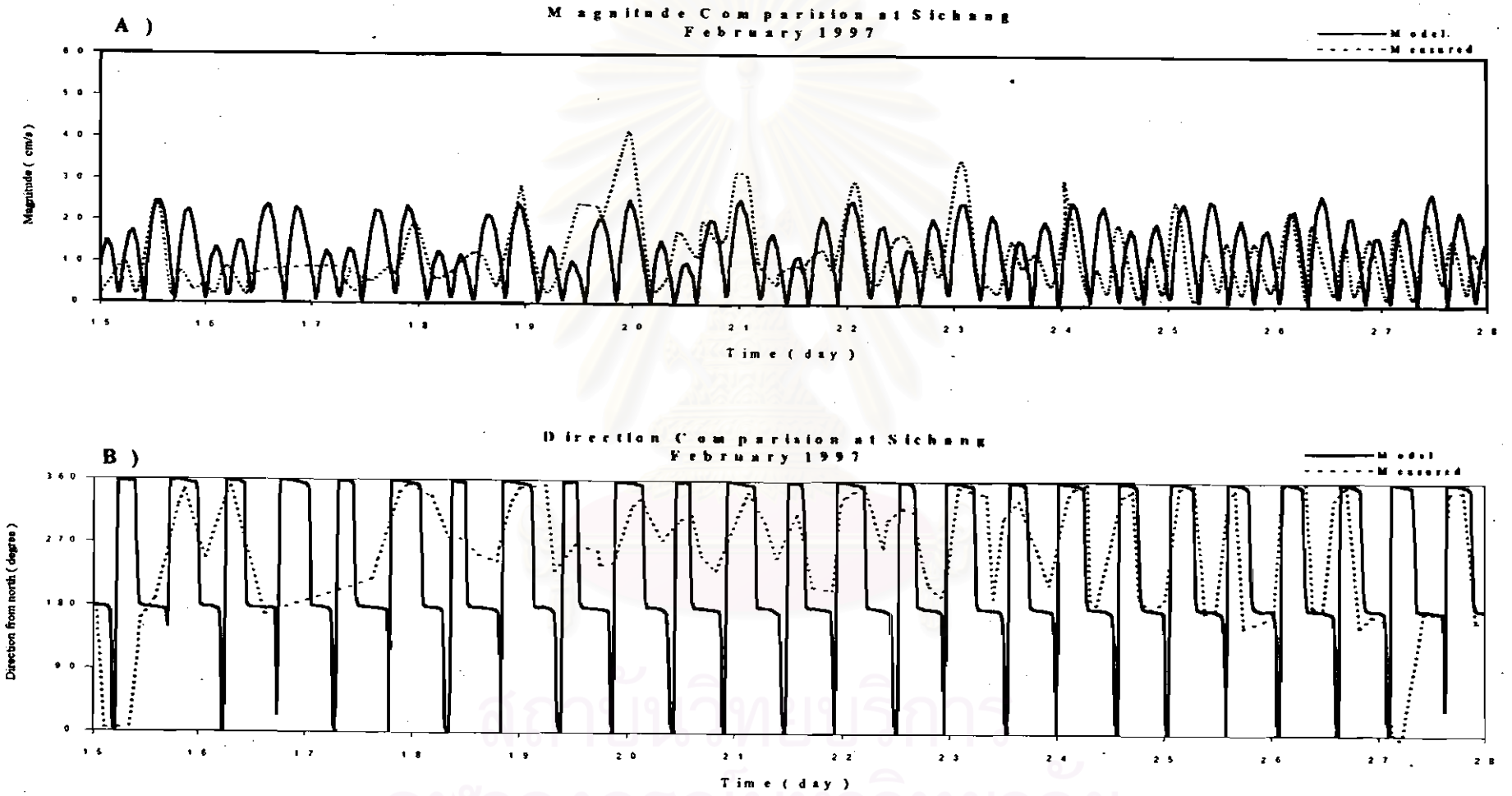


Figure 20. Comparison of measured and computed current at Ko Sichang in February 1997

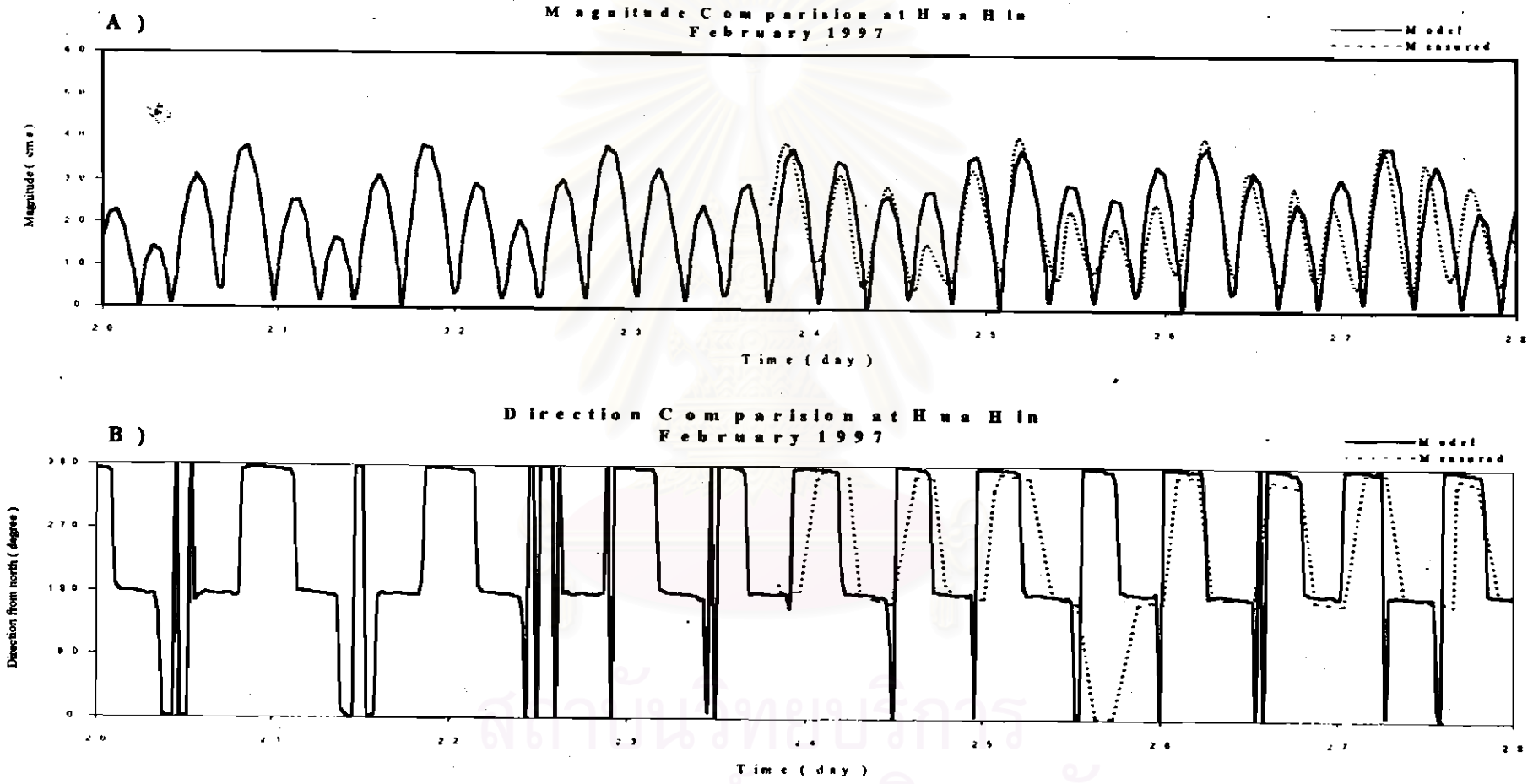


Figure 21. Comparison of measured and computed current at Hua Hin in February 1997

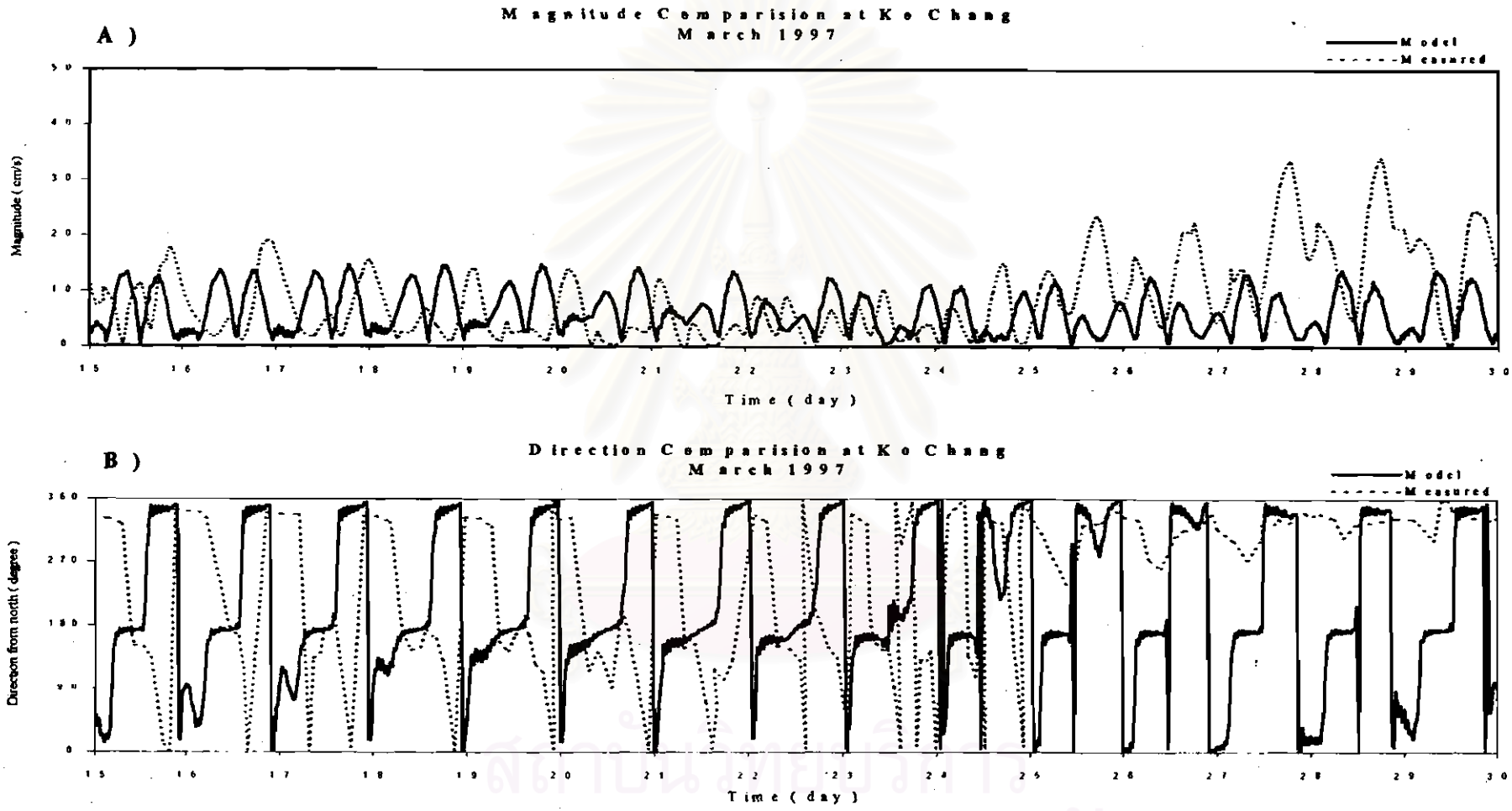


Figure 22. Comparison of measured and computed current at Ko Chang in March 1997

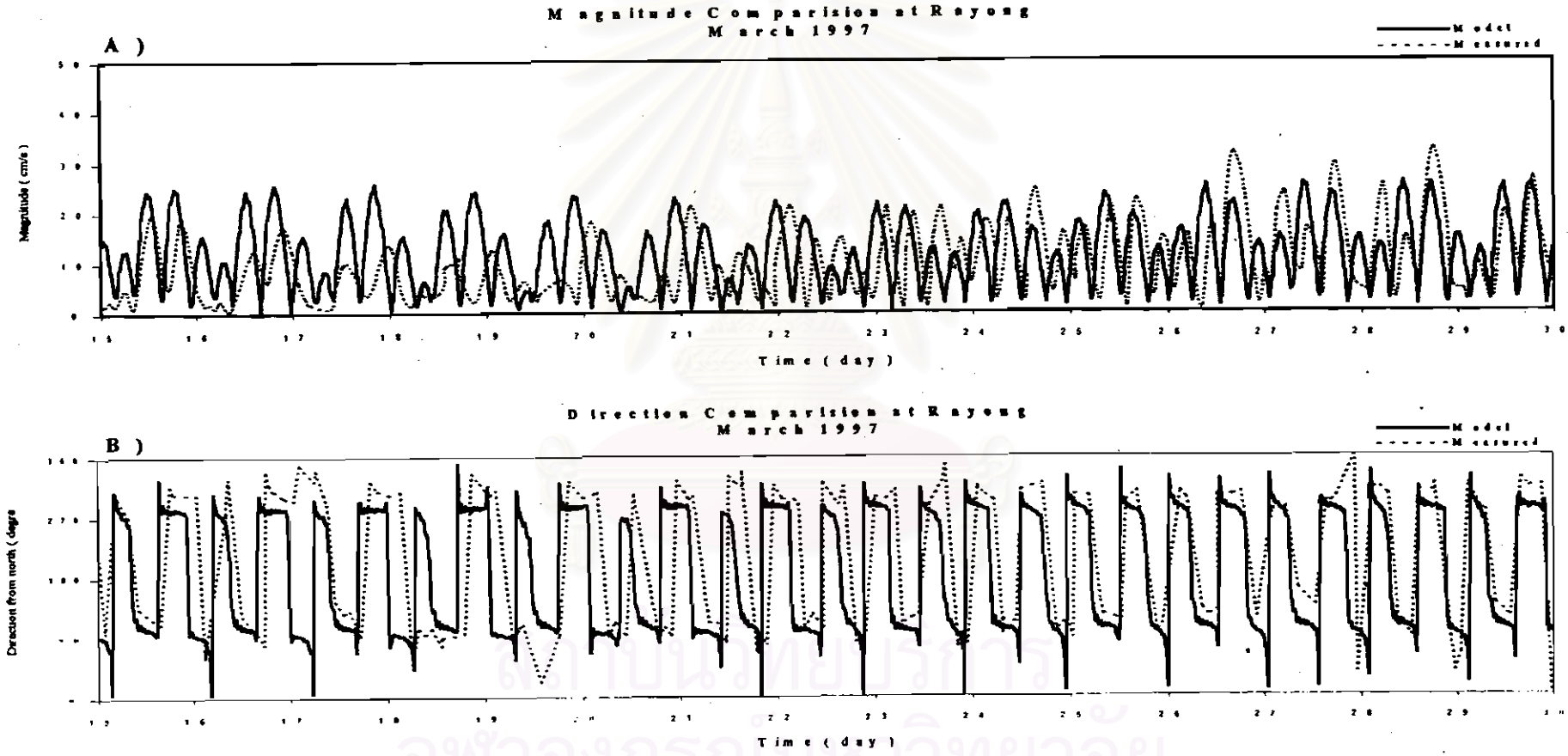


Figure 23. Comparison of measured and computed current at Rayong in March 1997

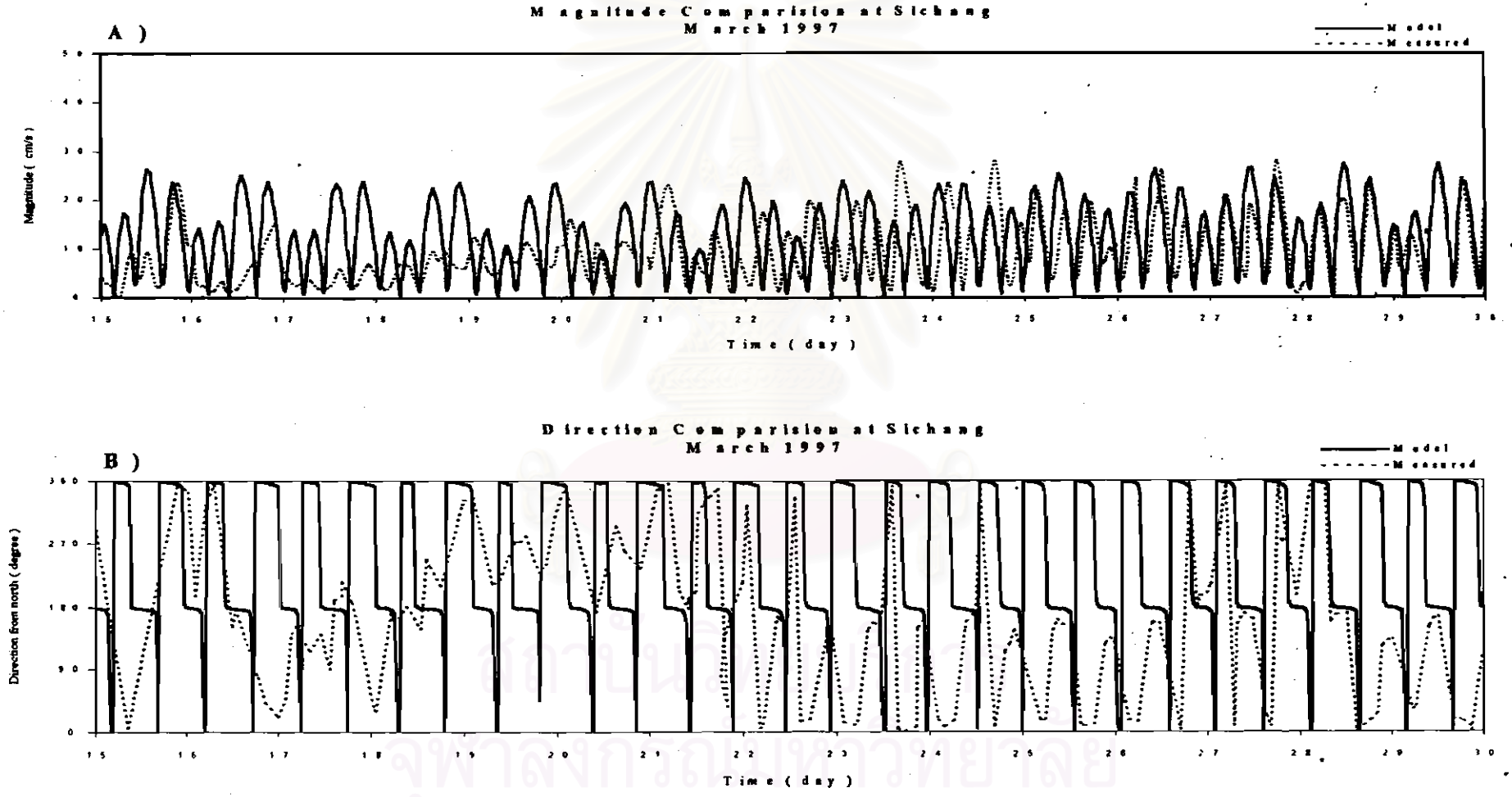


Figure 24. Comparison of measured and computed current at Sichang in March 1997

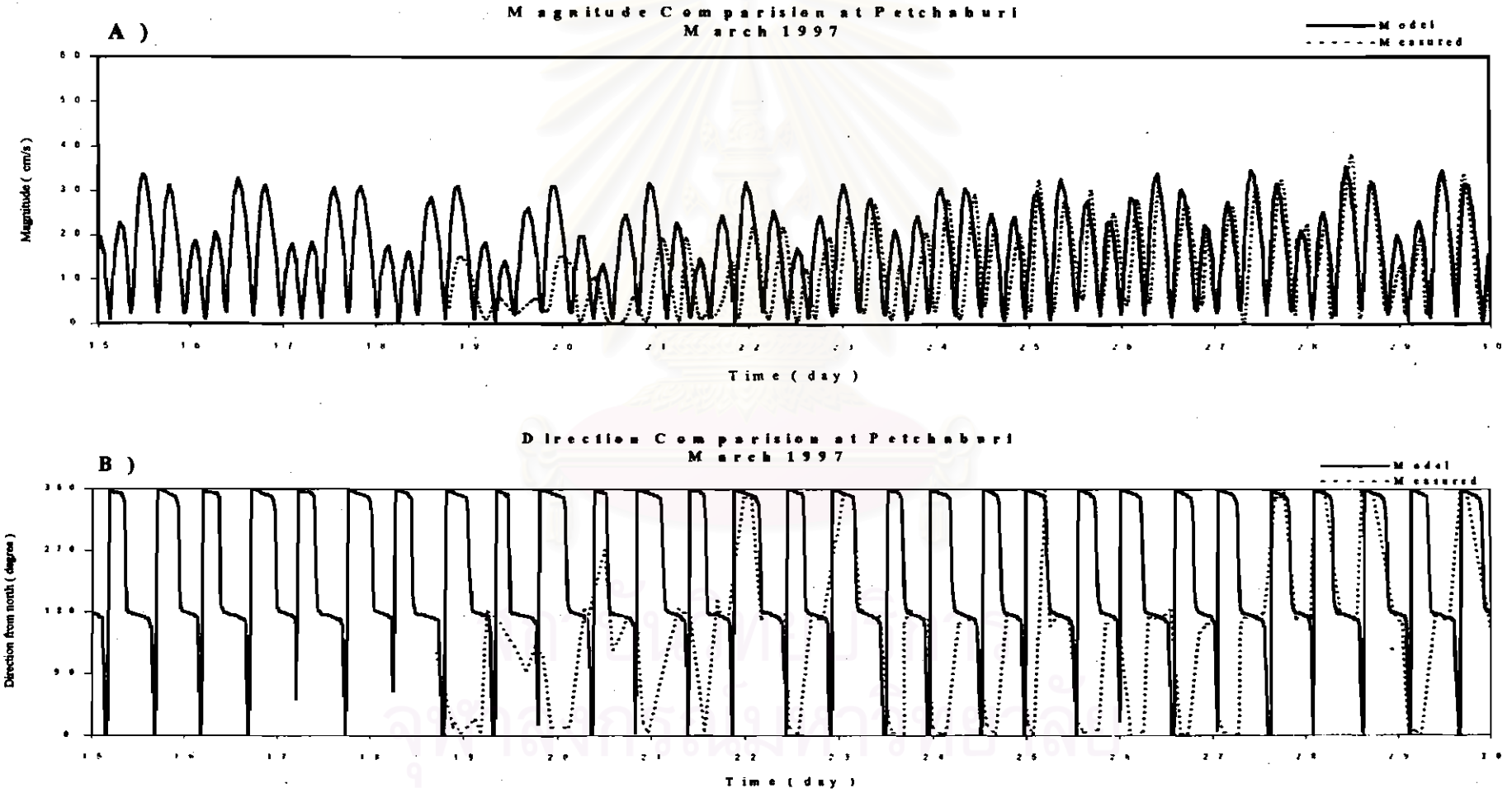


Figure 25. Comparison of measured and computed current at Petchaburi in March 1997

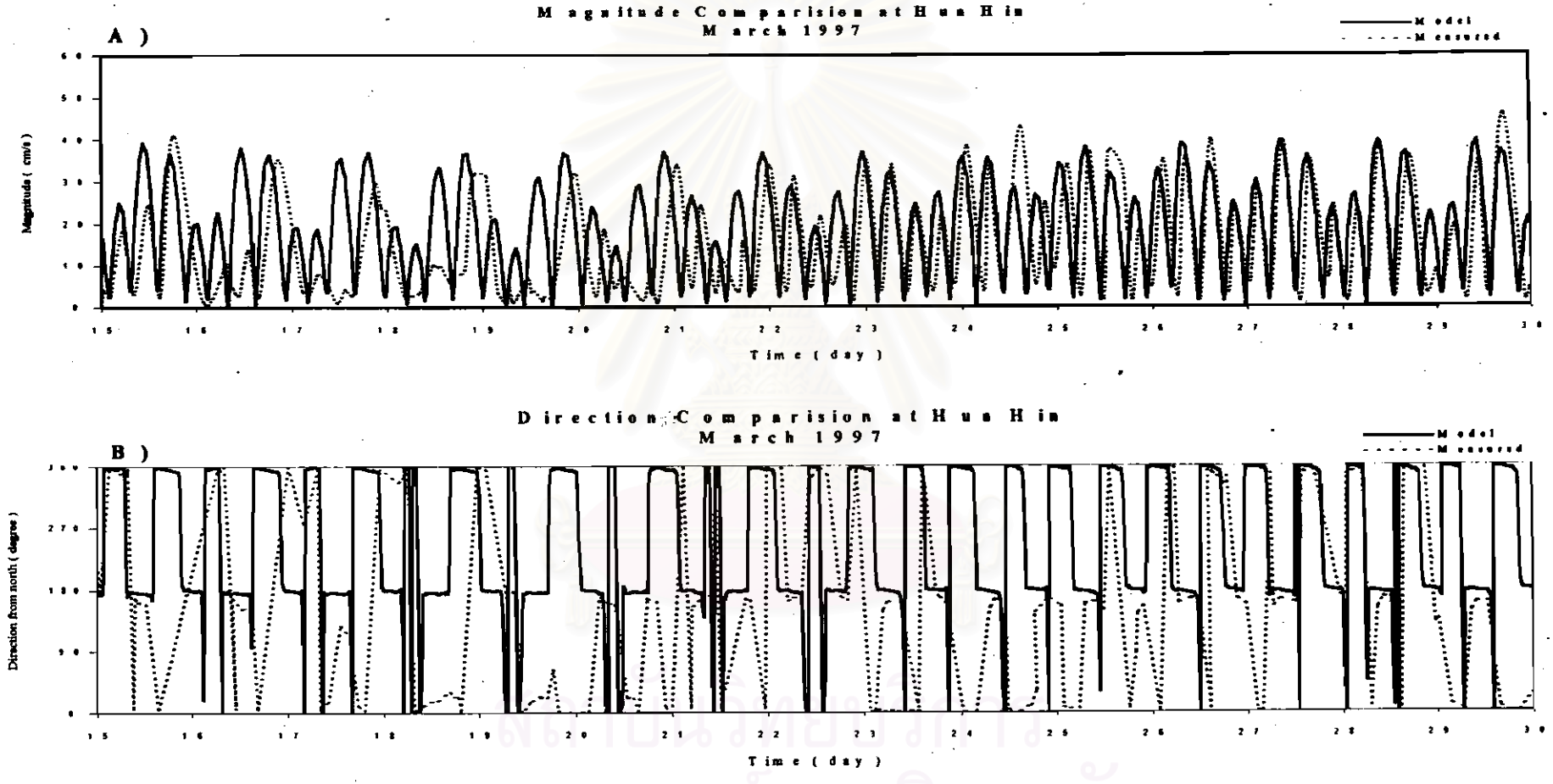


Figure 26. Comparison of measured and computed current at Hua Hin in March 1997

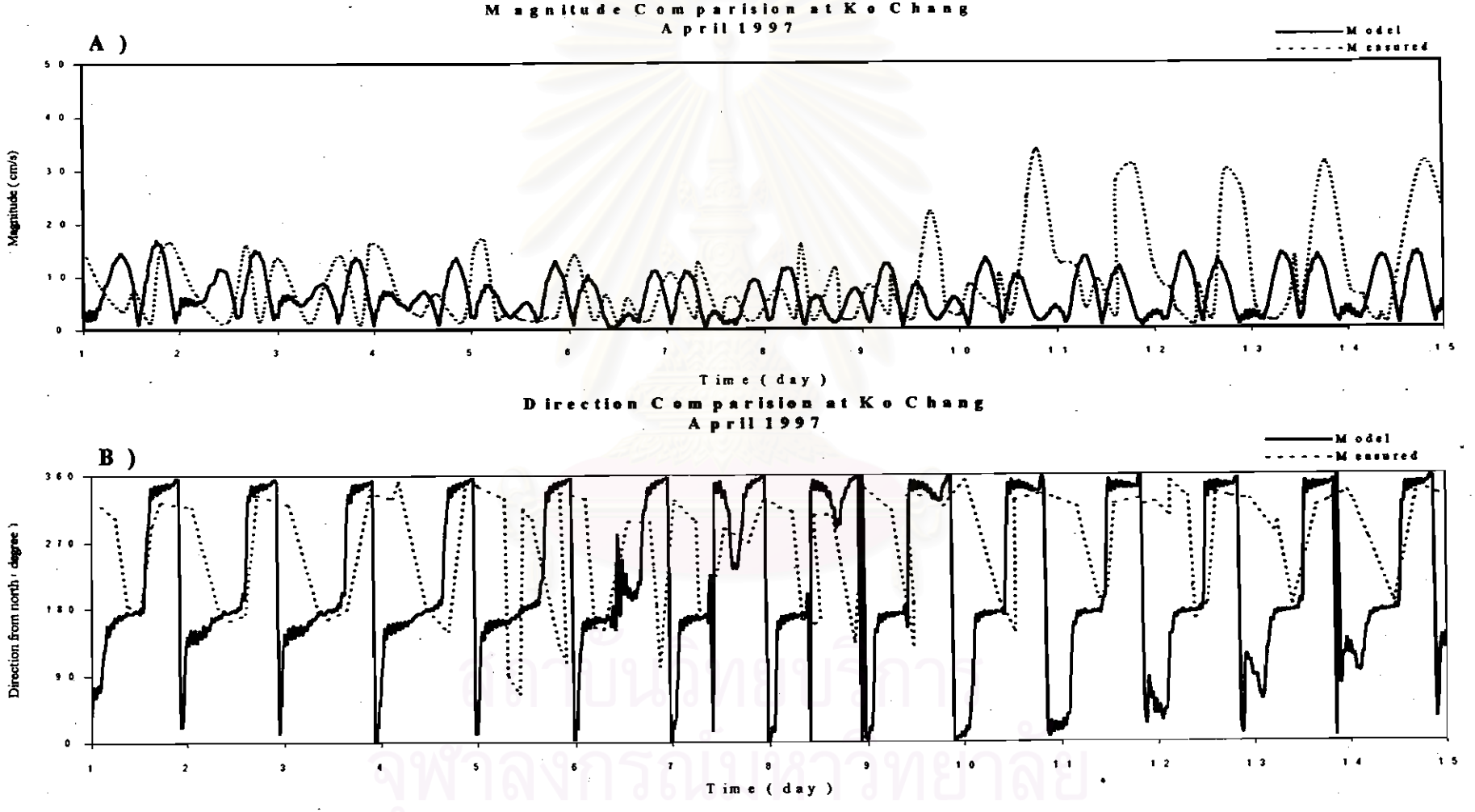


Figure 27. Comparison of measured and computed current at Ko Chang in April 1997

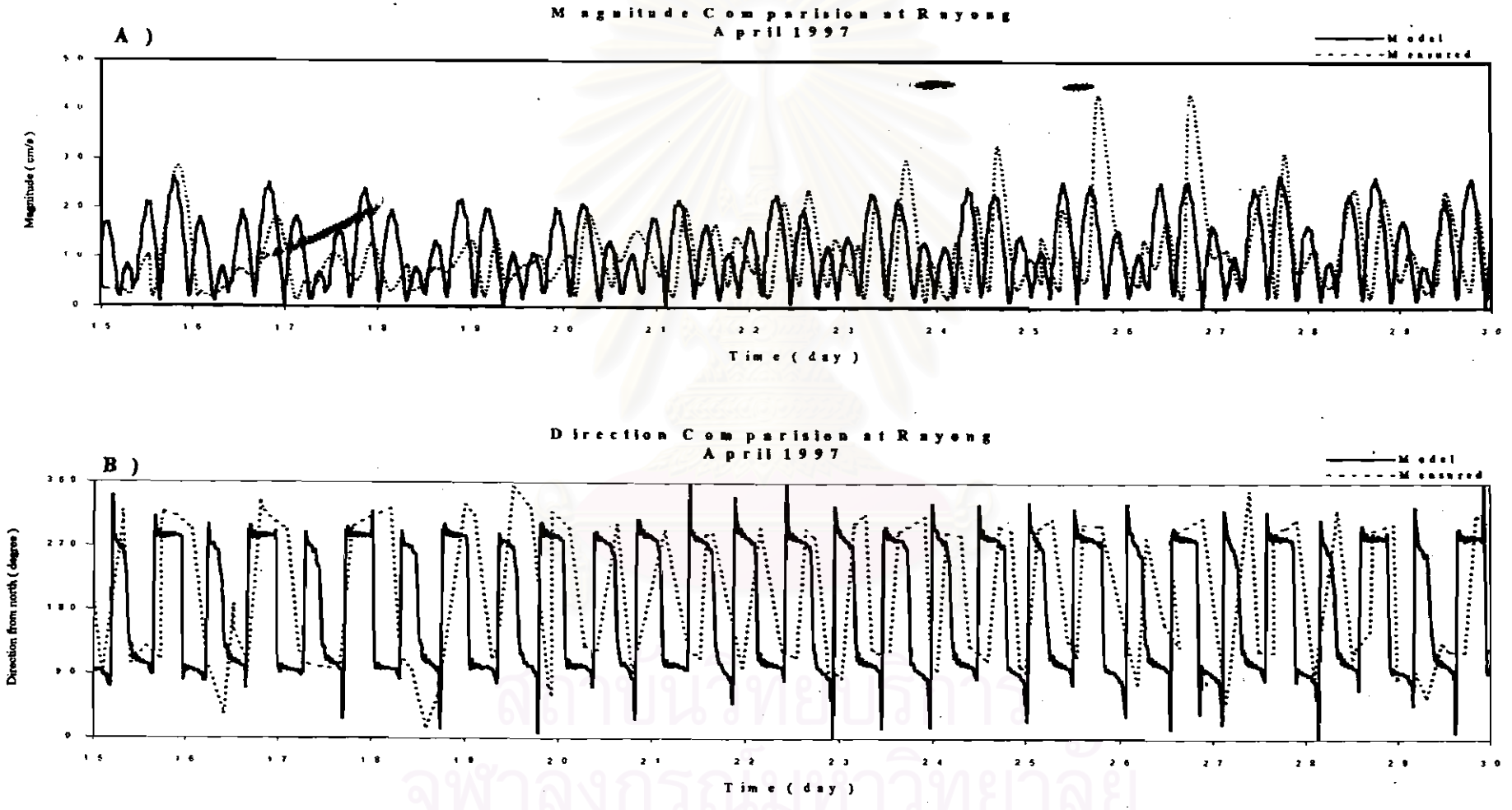


Figure 28. Comparison of measured and computed current at Rayong in April 1997

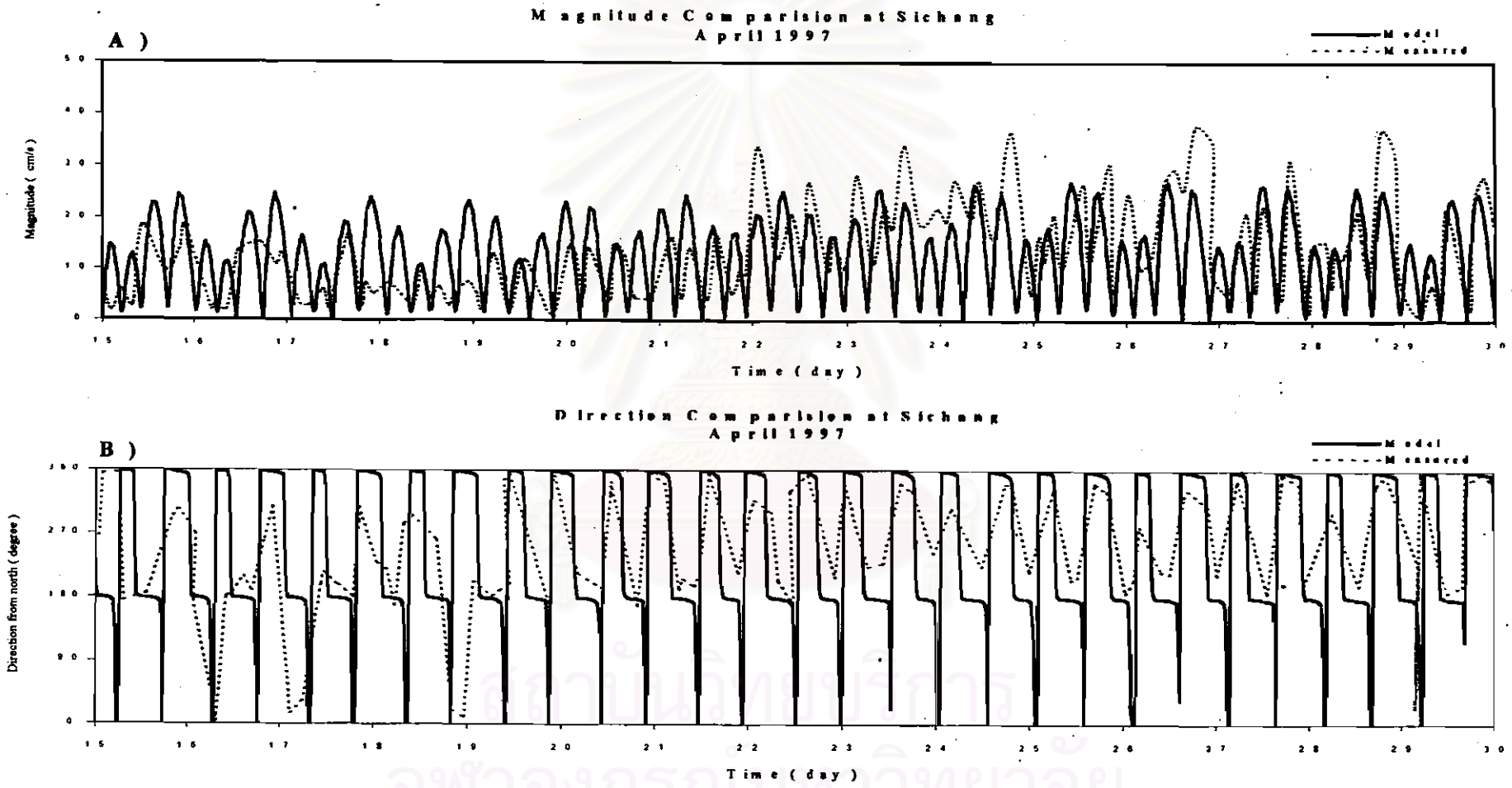


Figure 29. Comparison of measured and computed current at Ko Sichang in April 1997

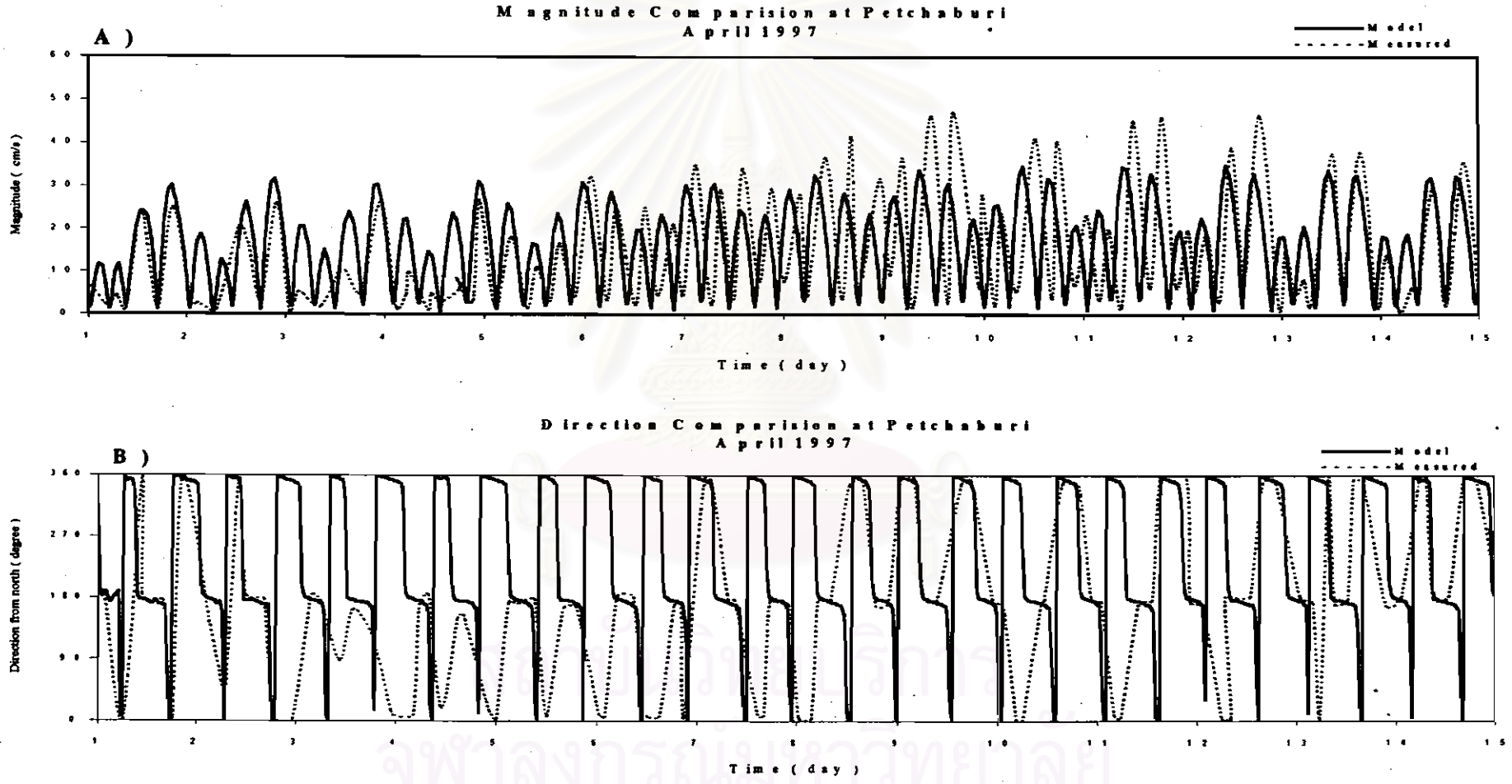


Figure 30. Comparison of measured and computed current at Petchaburi in March 1997

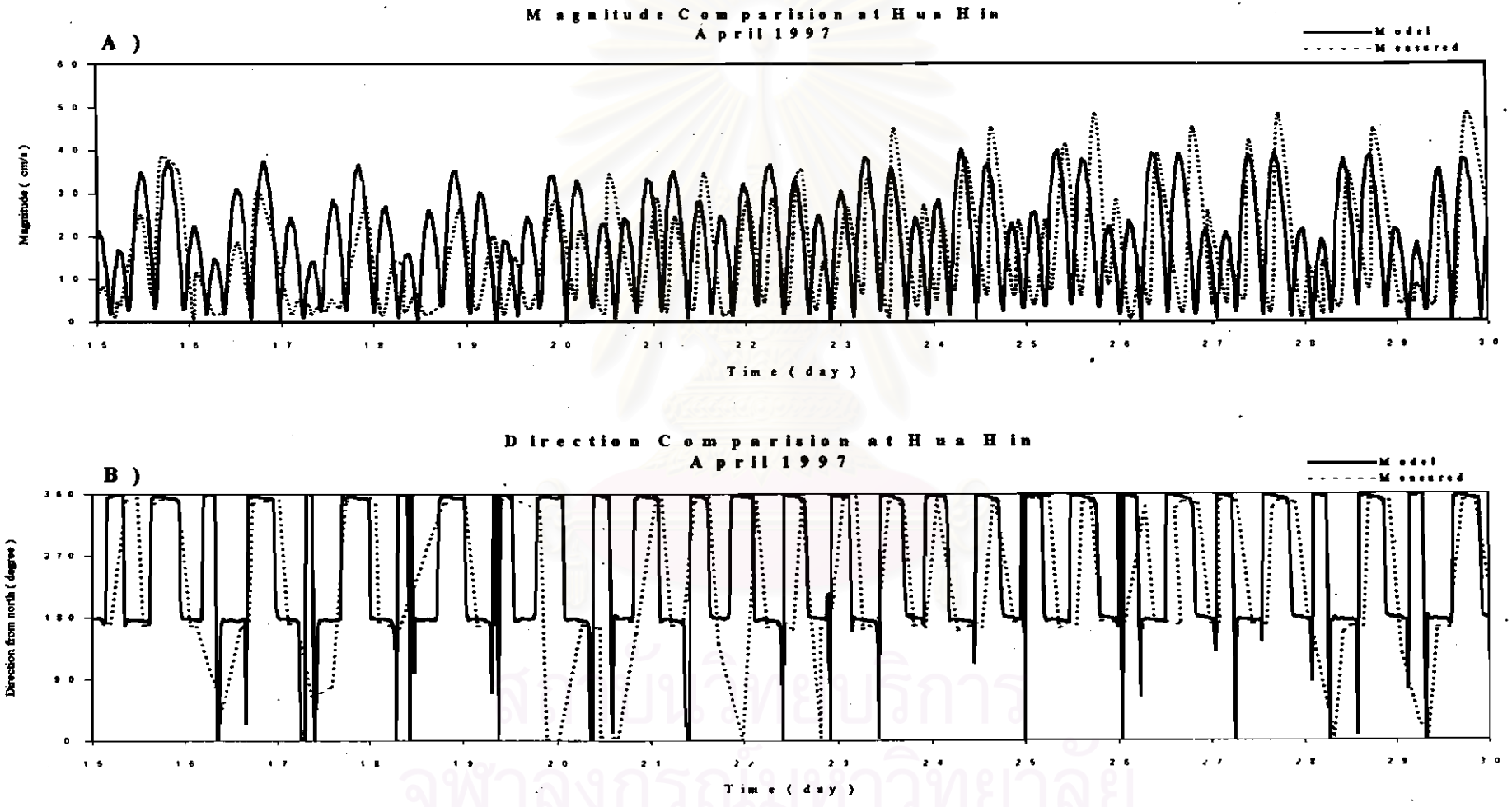


Figure 31. Comparison of measured and computed current at Hua Hin in April 1997

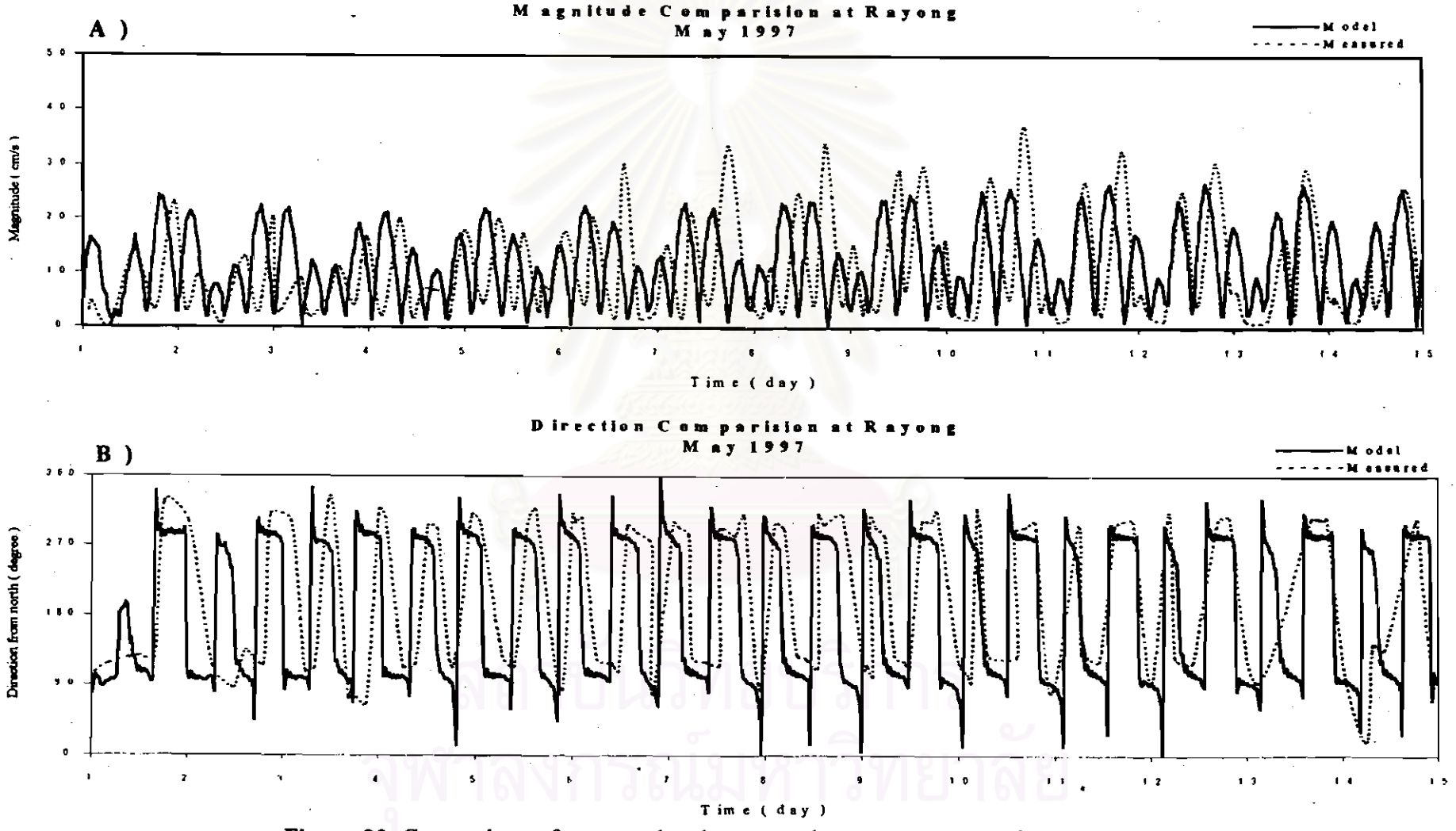


Figure 32. Comparison of measured and computed current at Rayong in May 1997

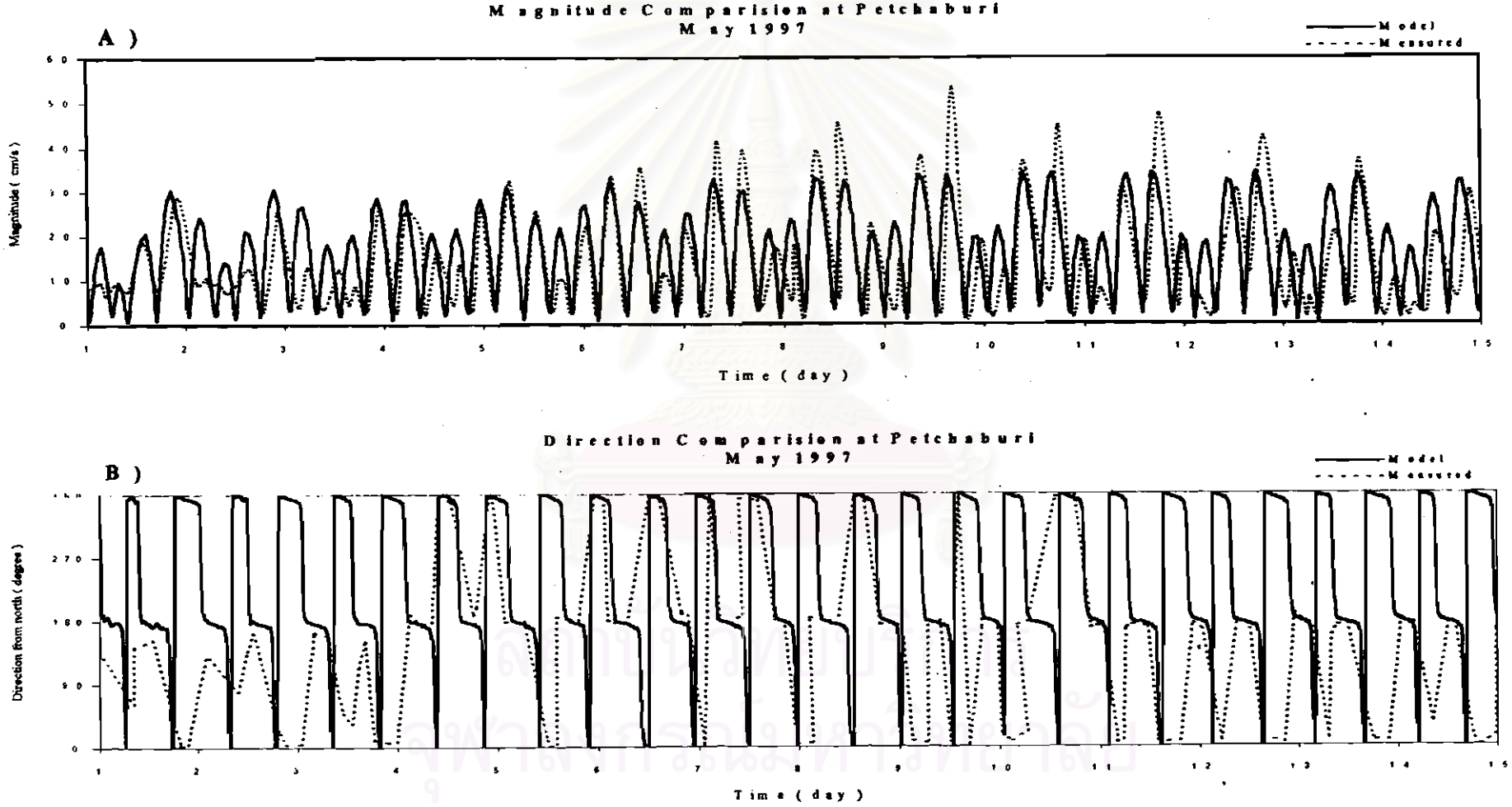


Figure 33. Comparison of measured and computed current at Petchaburi in May 1997

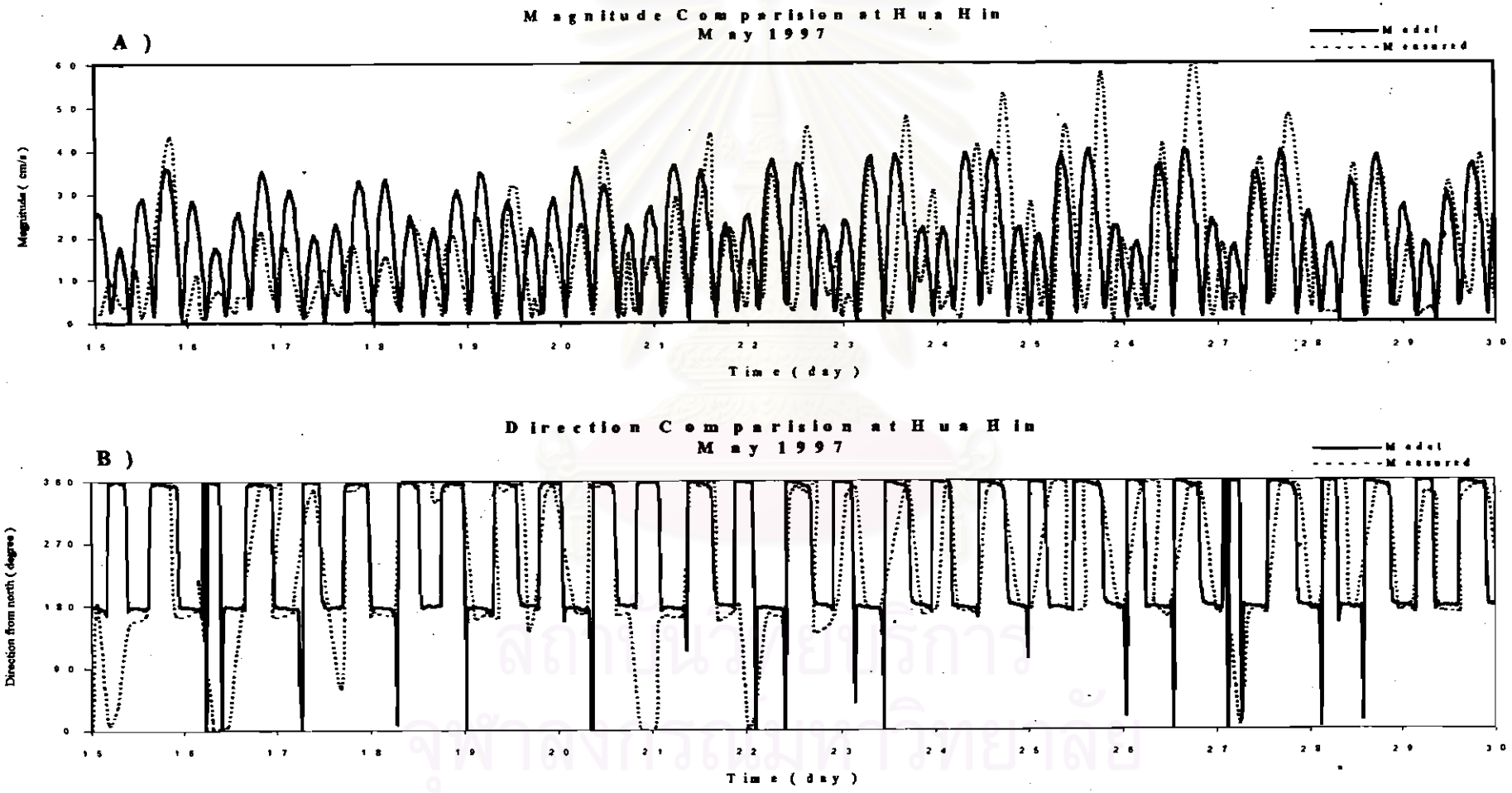


Figure 34. Comparison of measured and computed current at Hua Hin in May 1997

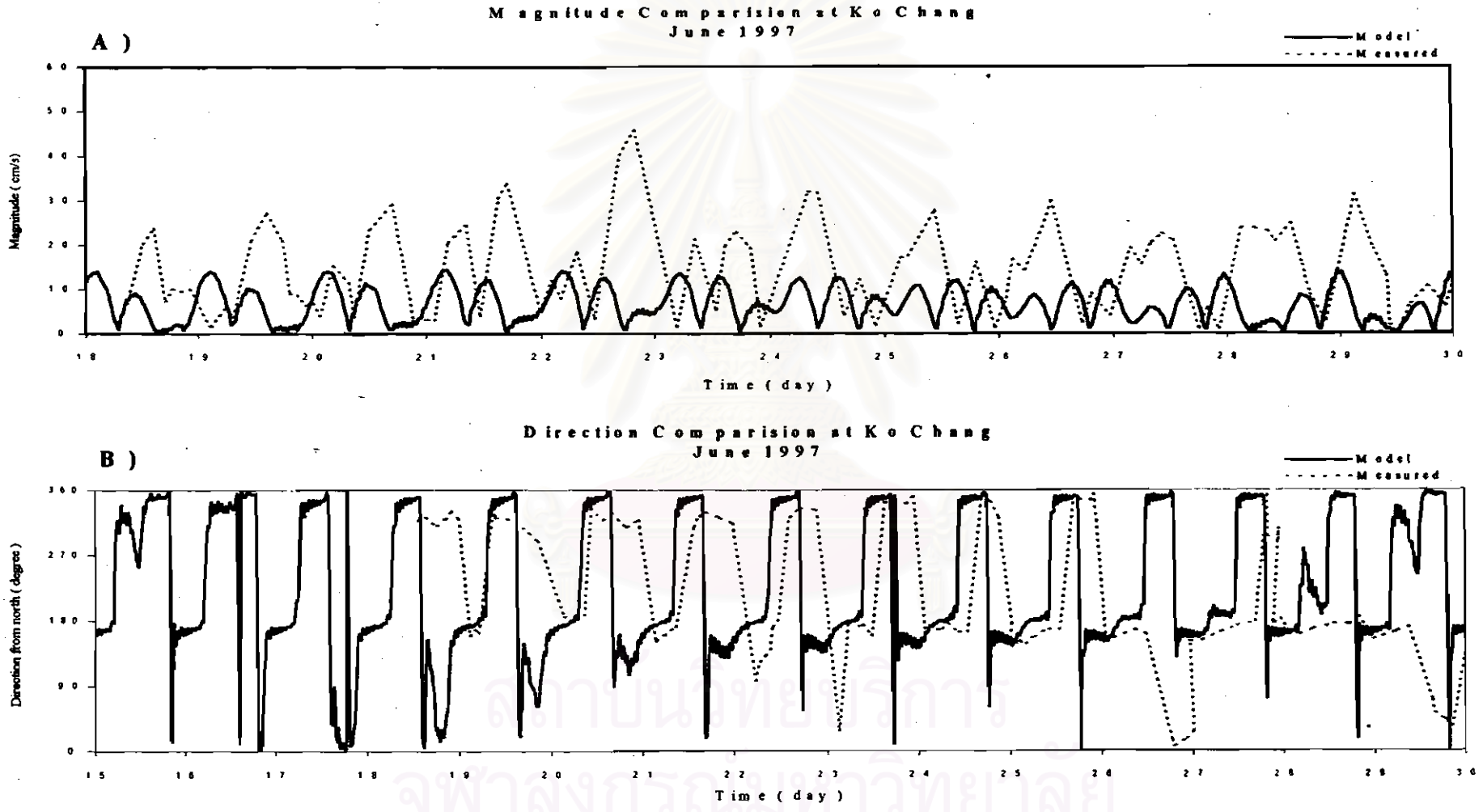


Figure 35. Comparison of measured and computed current at Ko Chang in June 1997

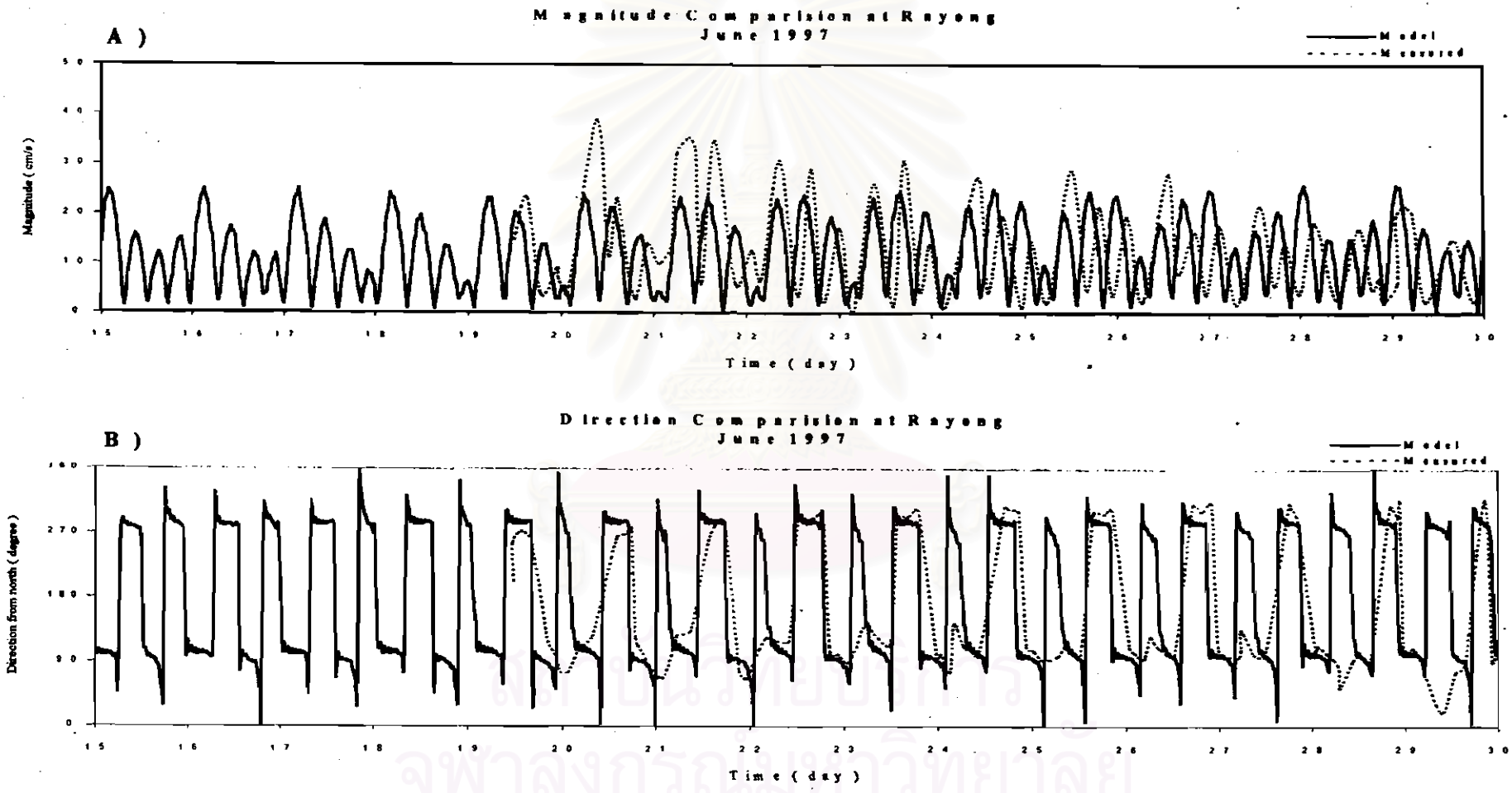


Figure 36. Comparison of measured and computed current at Rayong in June 1997

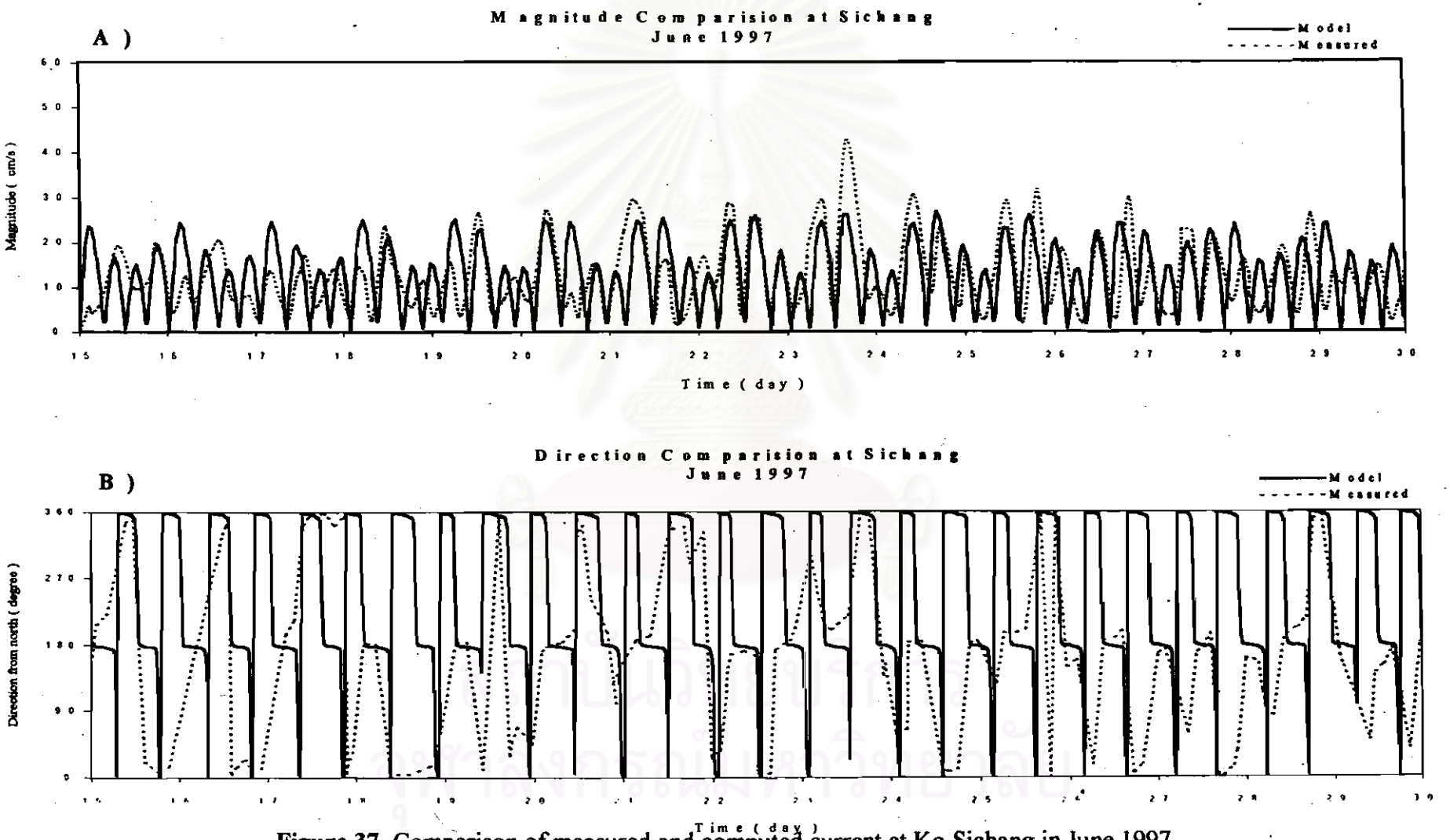


Figure 37. Comparison of measured and computed current at Ko Sichang in June 1997

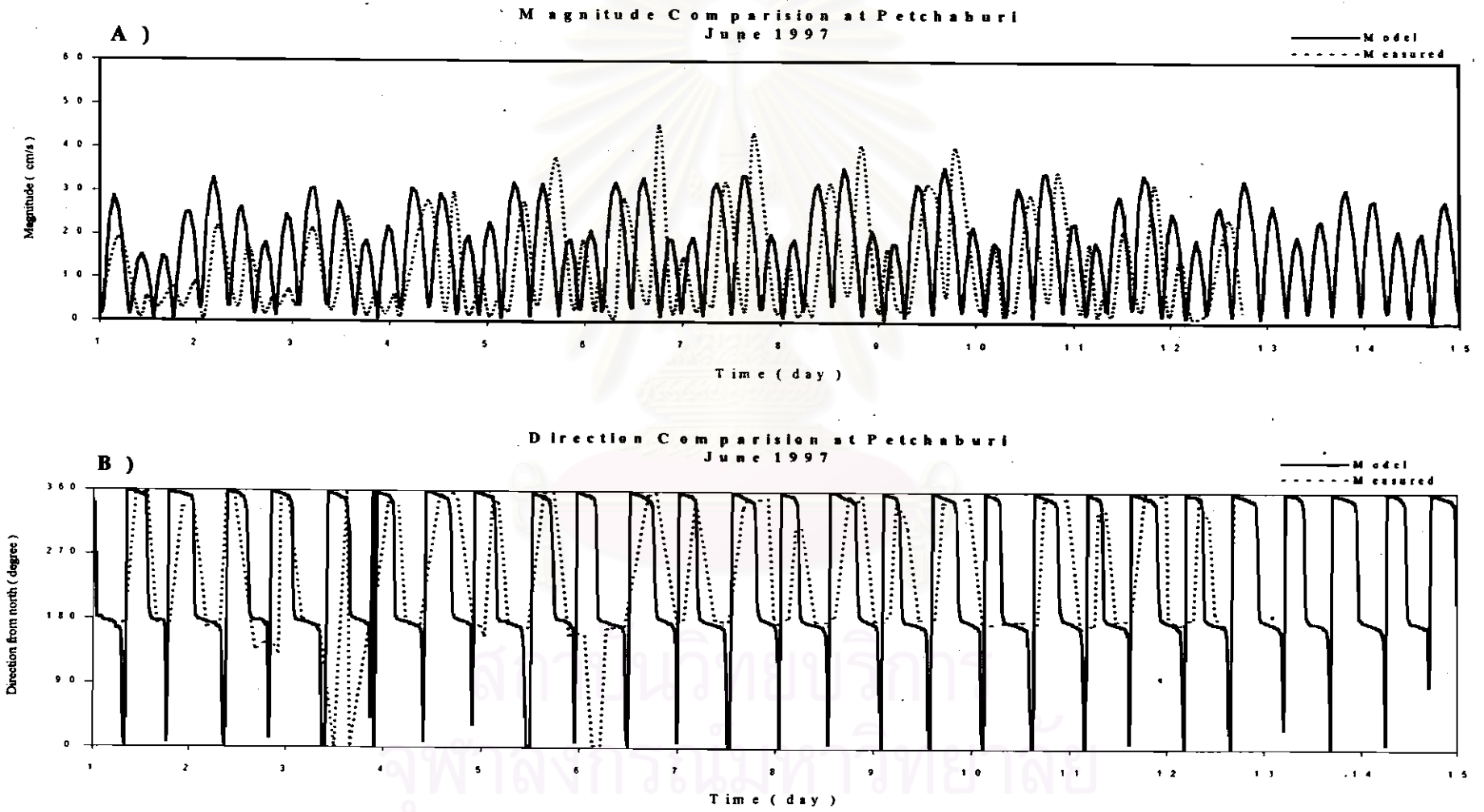


Figure 38. Comparison of measured and computed current at Petchaburi in June 1997

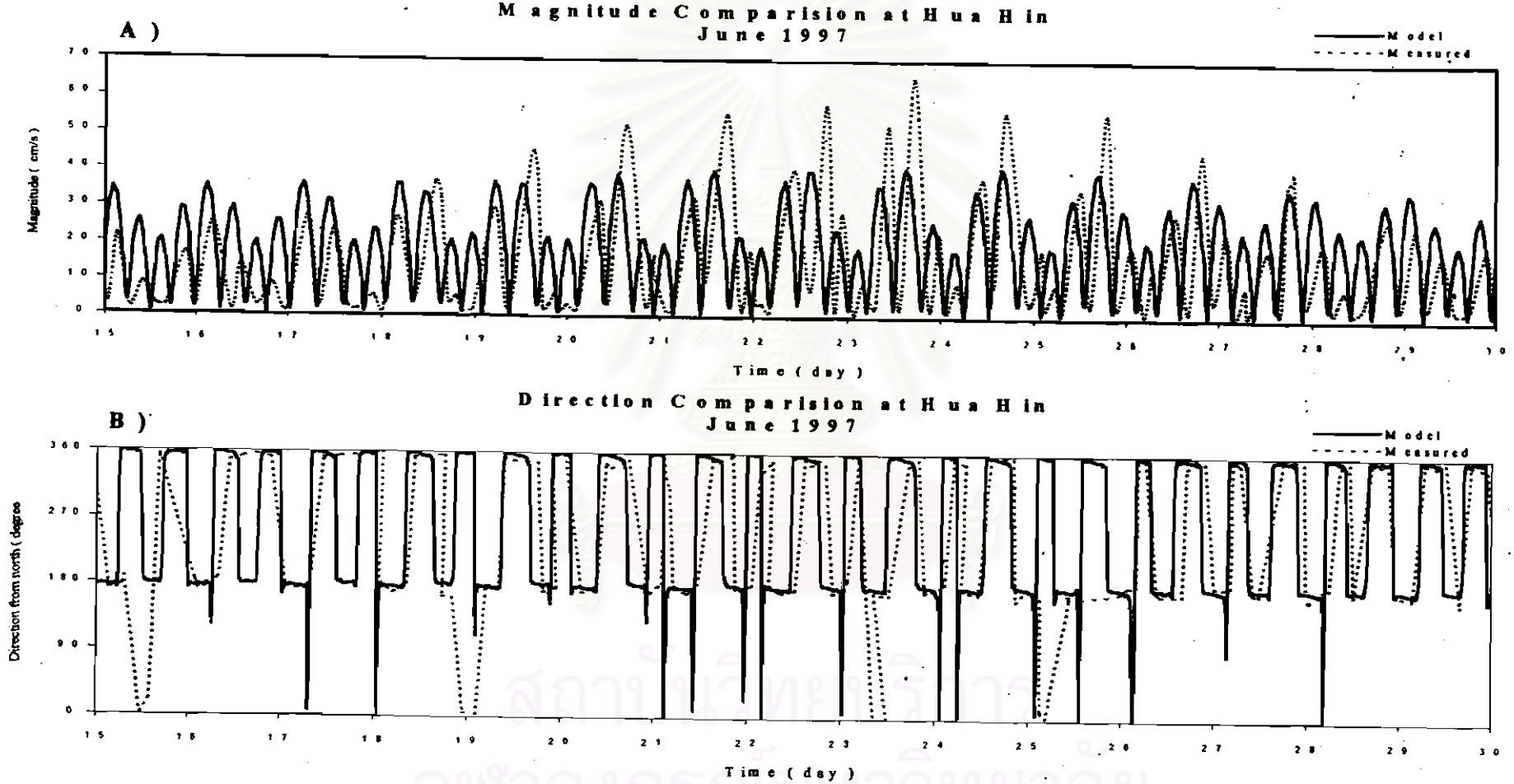


Figure 39. Comparison of measured and computed current at Hua Hin in June 1997

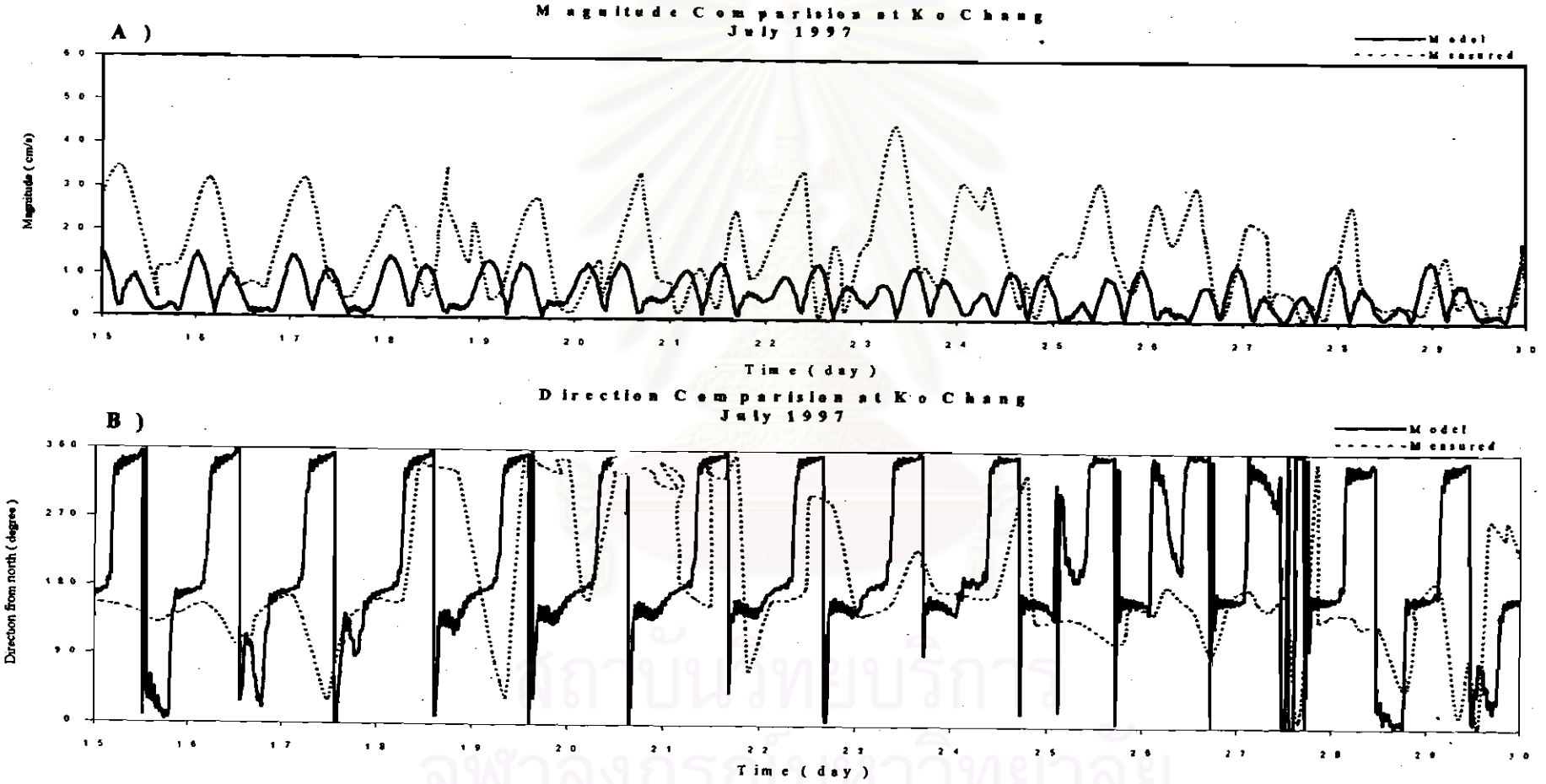


Figure 40. Comparison of measured and computed current at Ko Chang in July 1997

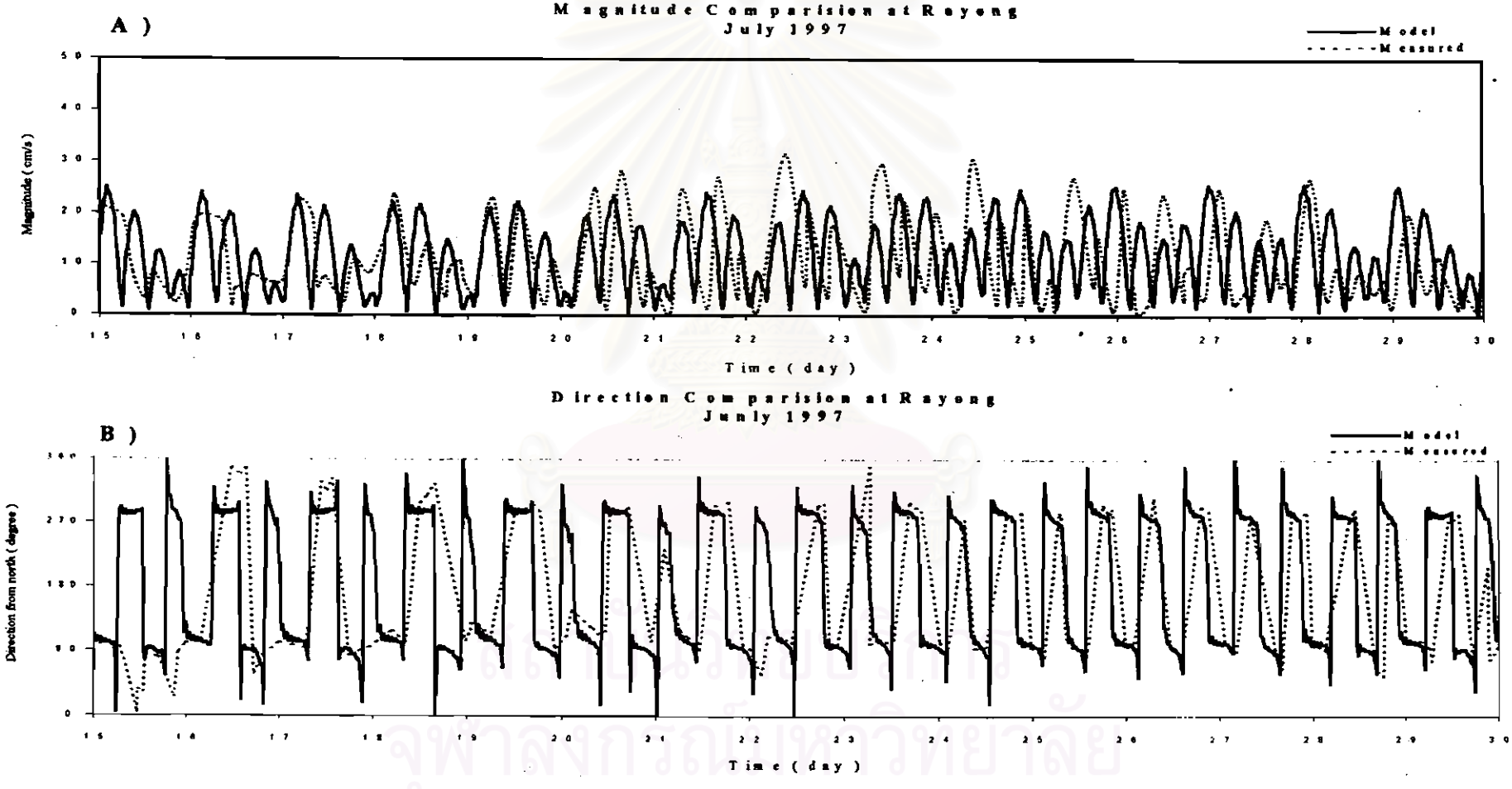


Figure 41. Comparison of measured and computed current at Rayong in July 1997

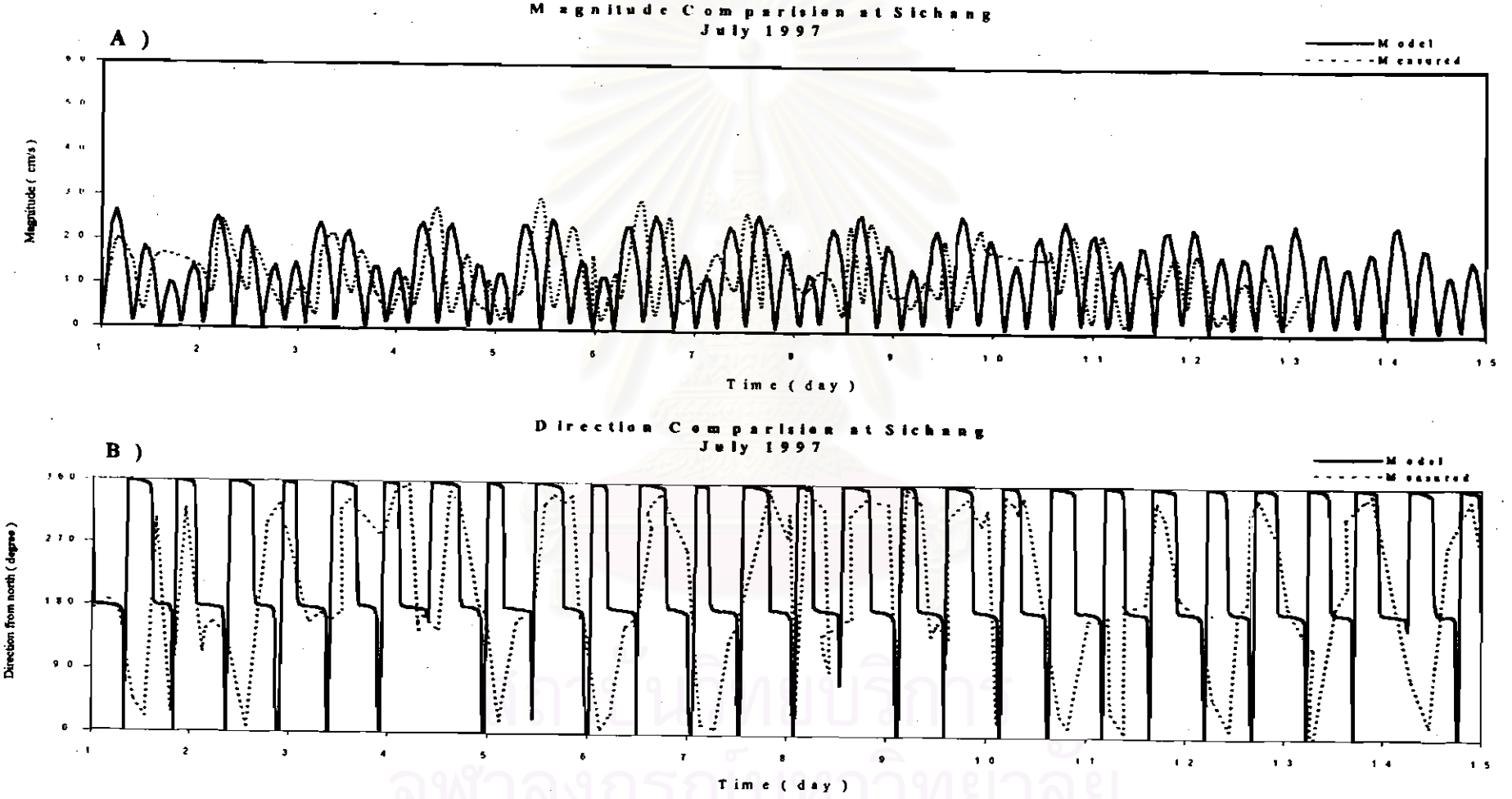


Figure 42. Comparison of measured and computed current at Ko Sichang in July 1997

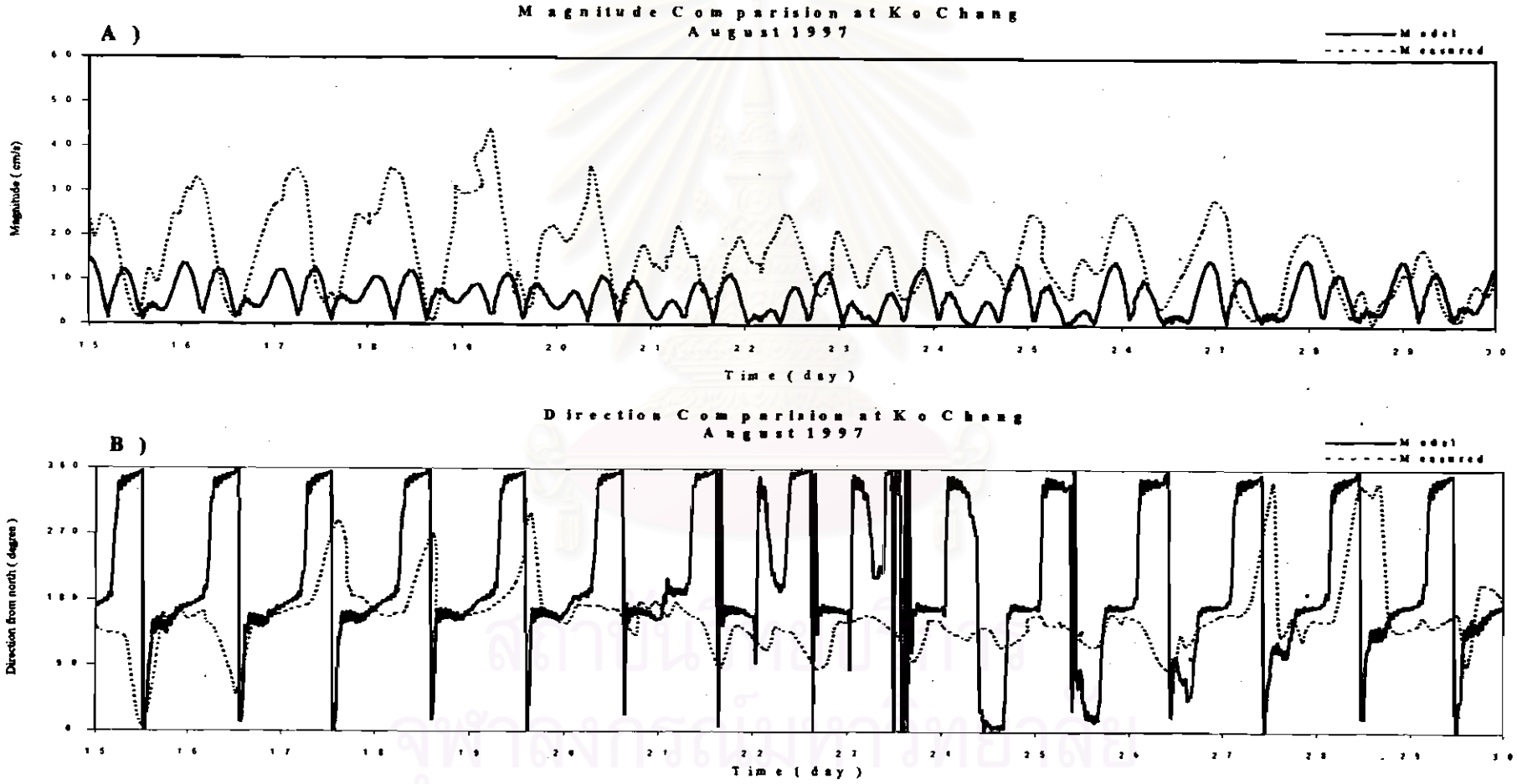


Figure 43. Comparison of measured and computed current at Ko Chang in August 1997

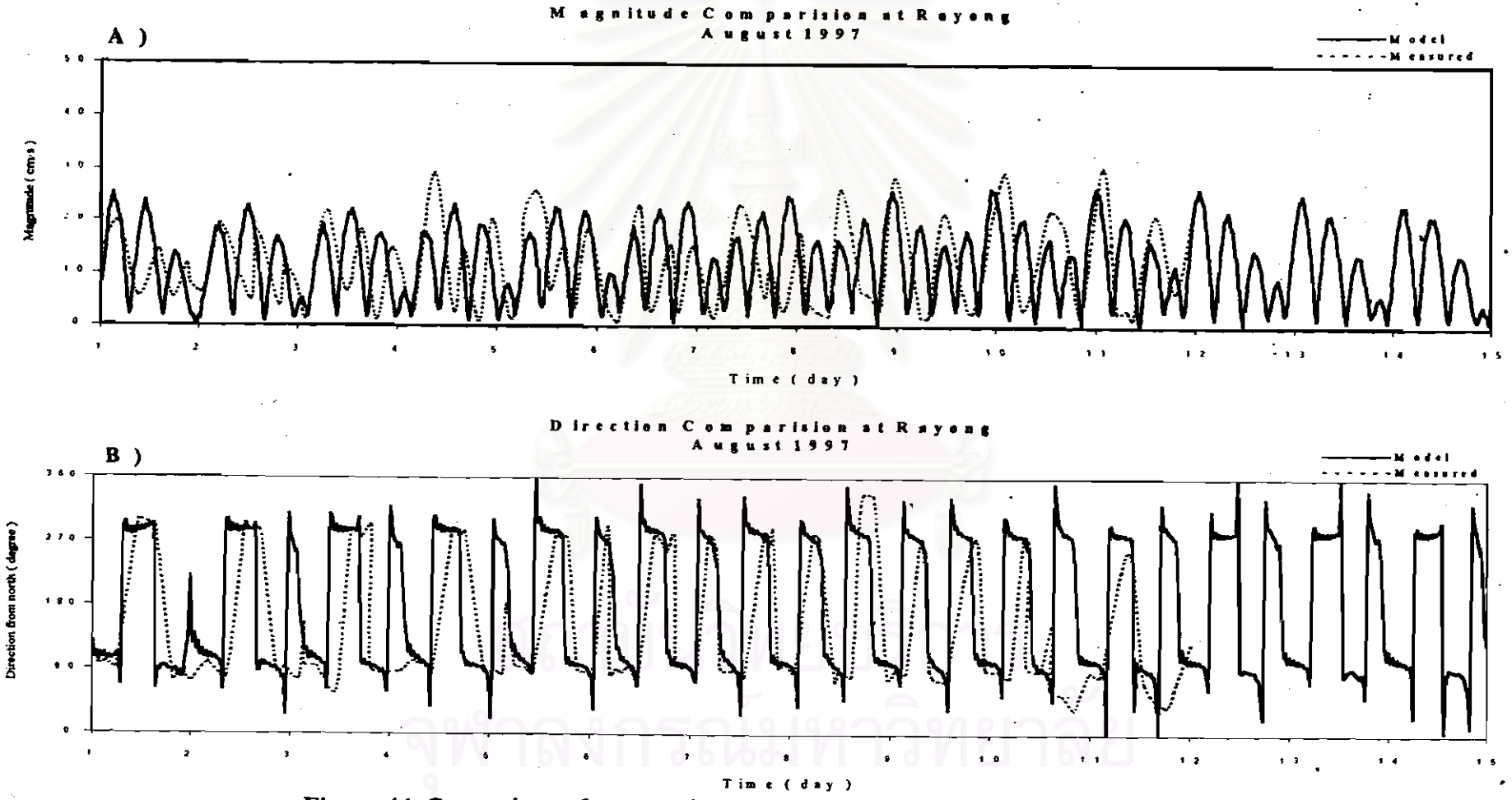


Figure 44. Comparison of measured and computed current at Rayong in August 1997

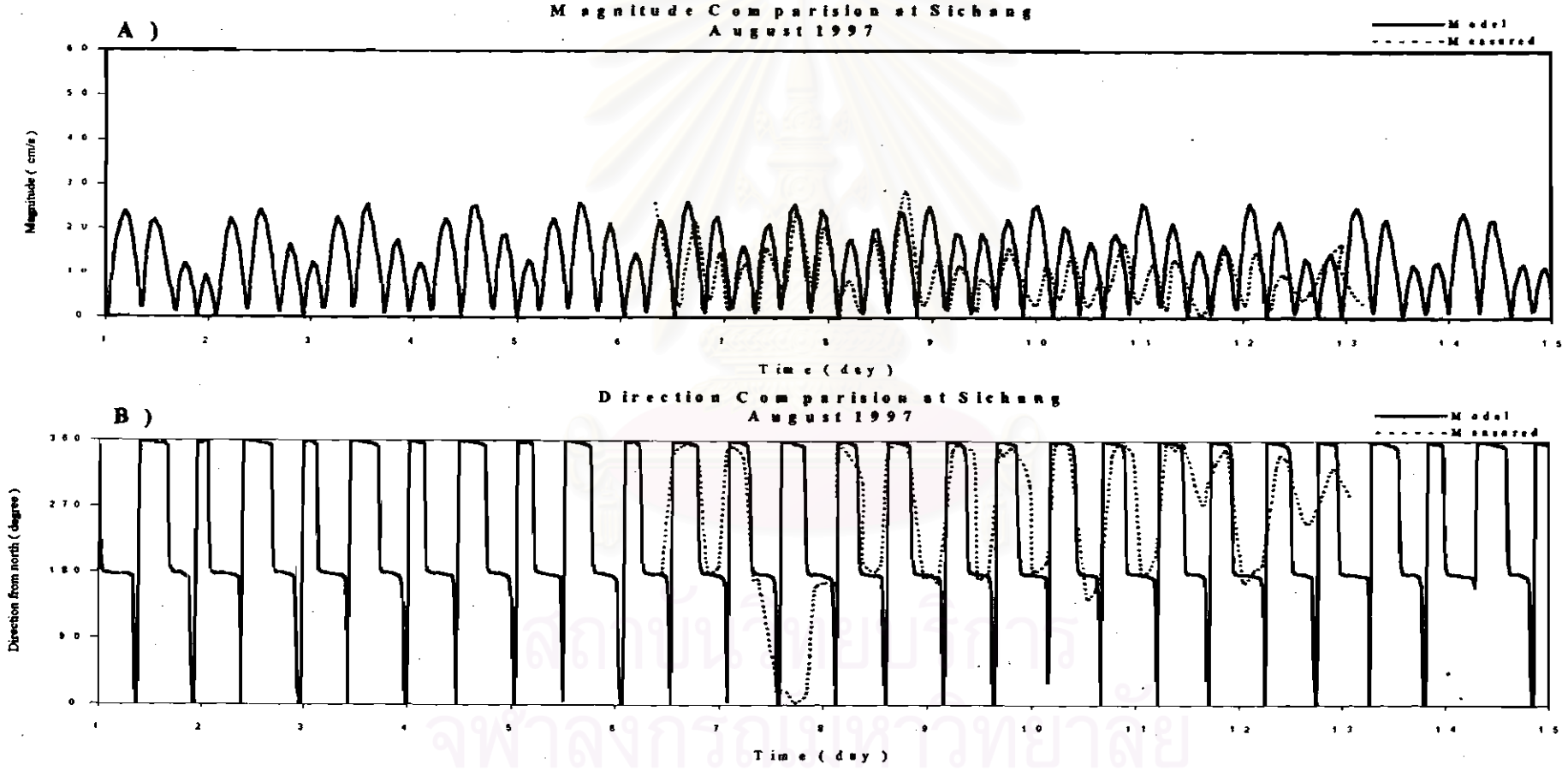


Figure 45. Comparison of measured and computed current at Ko Sichang in August 1997

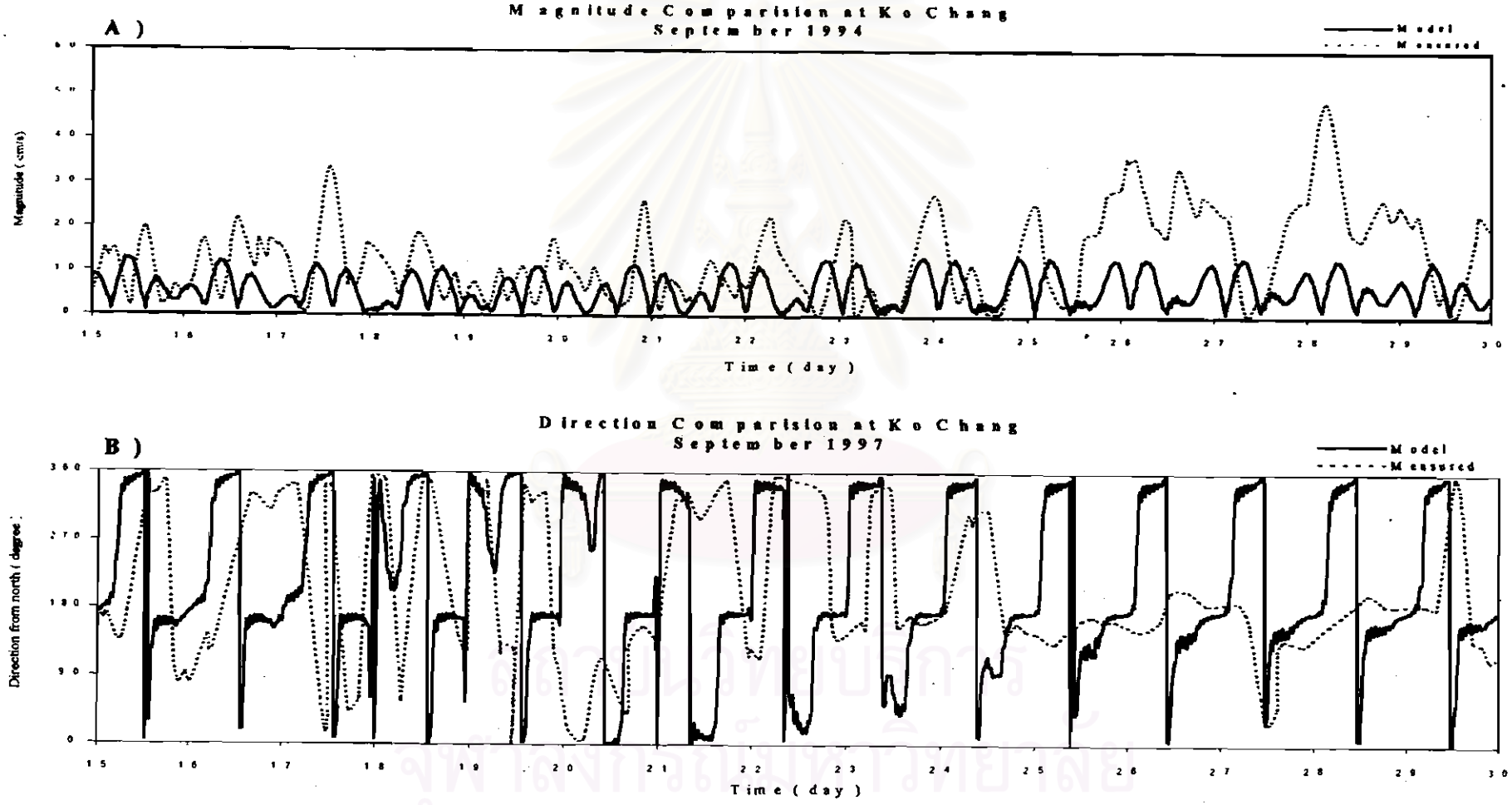


Figure 46. Comparison of measureed and computed current at Ko Chang in September 1997

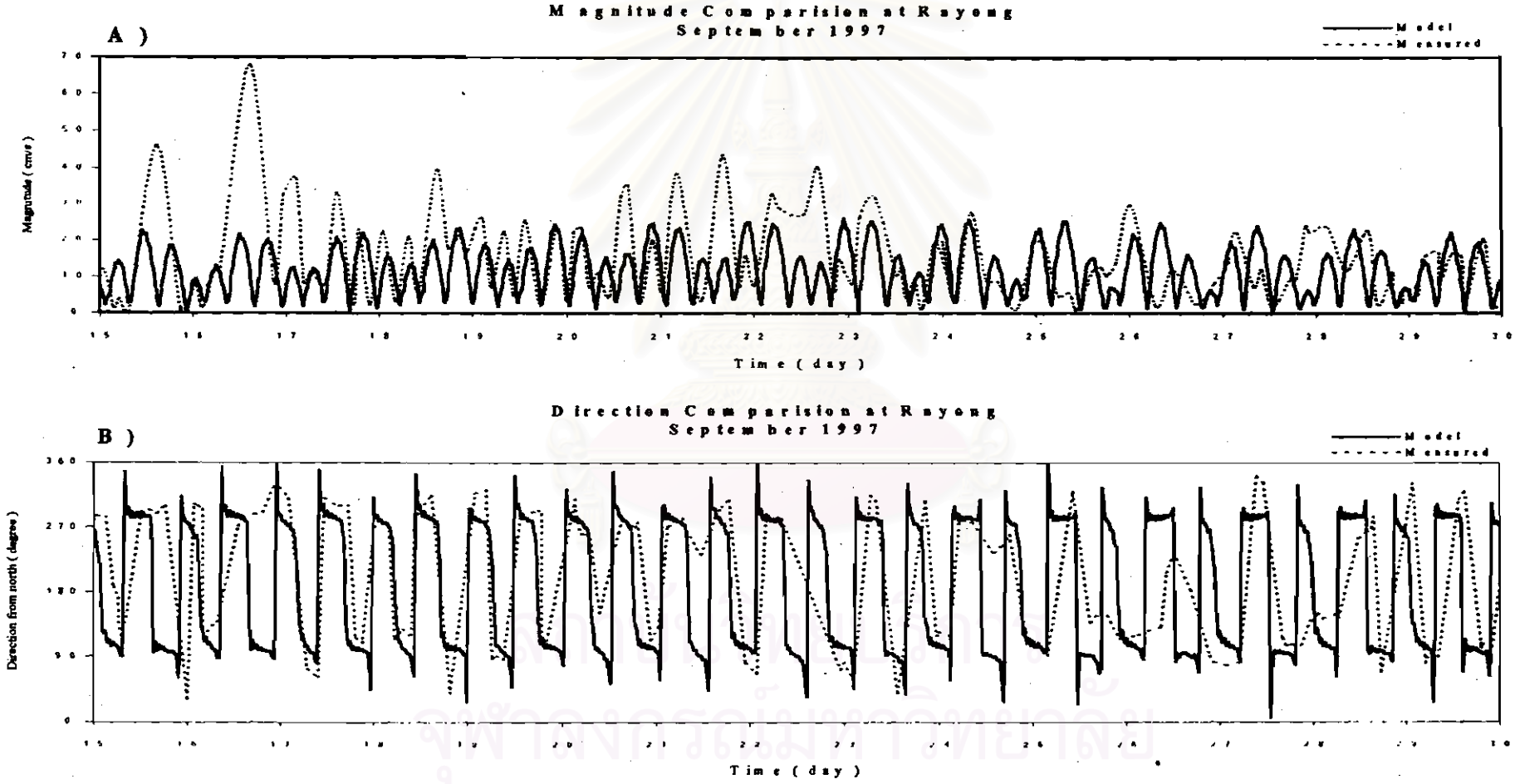


Figure 47. Comparison of measured and computed current at Rayong in September 1997

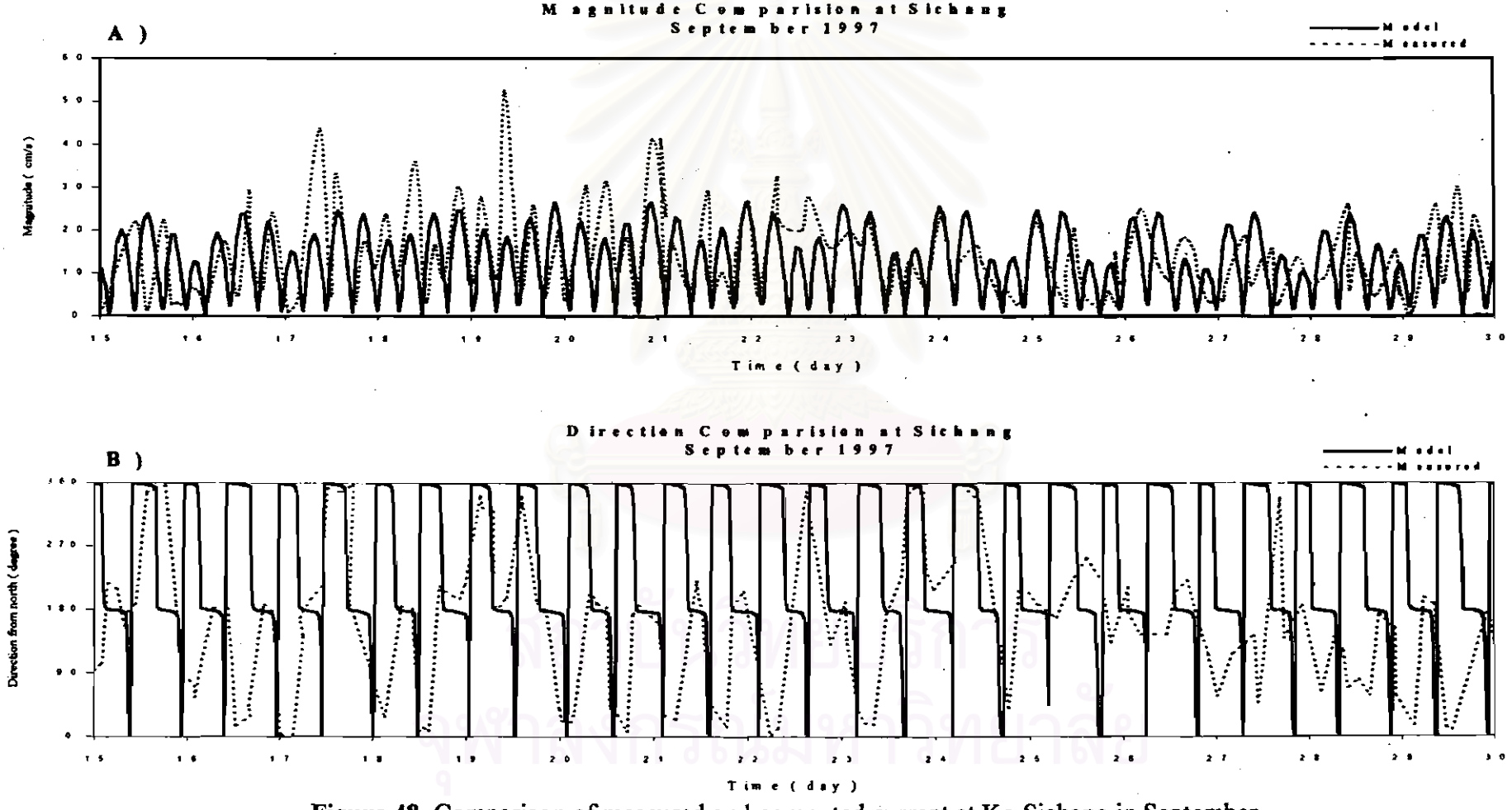


Figure 48. Comparison of measured and computed current at Ko Sichang in September

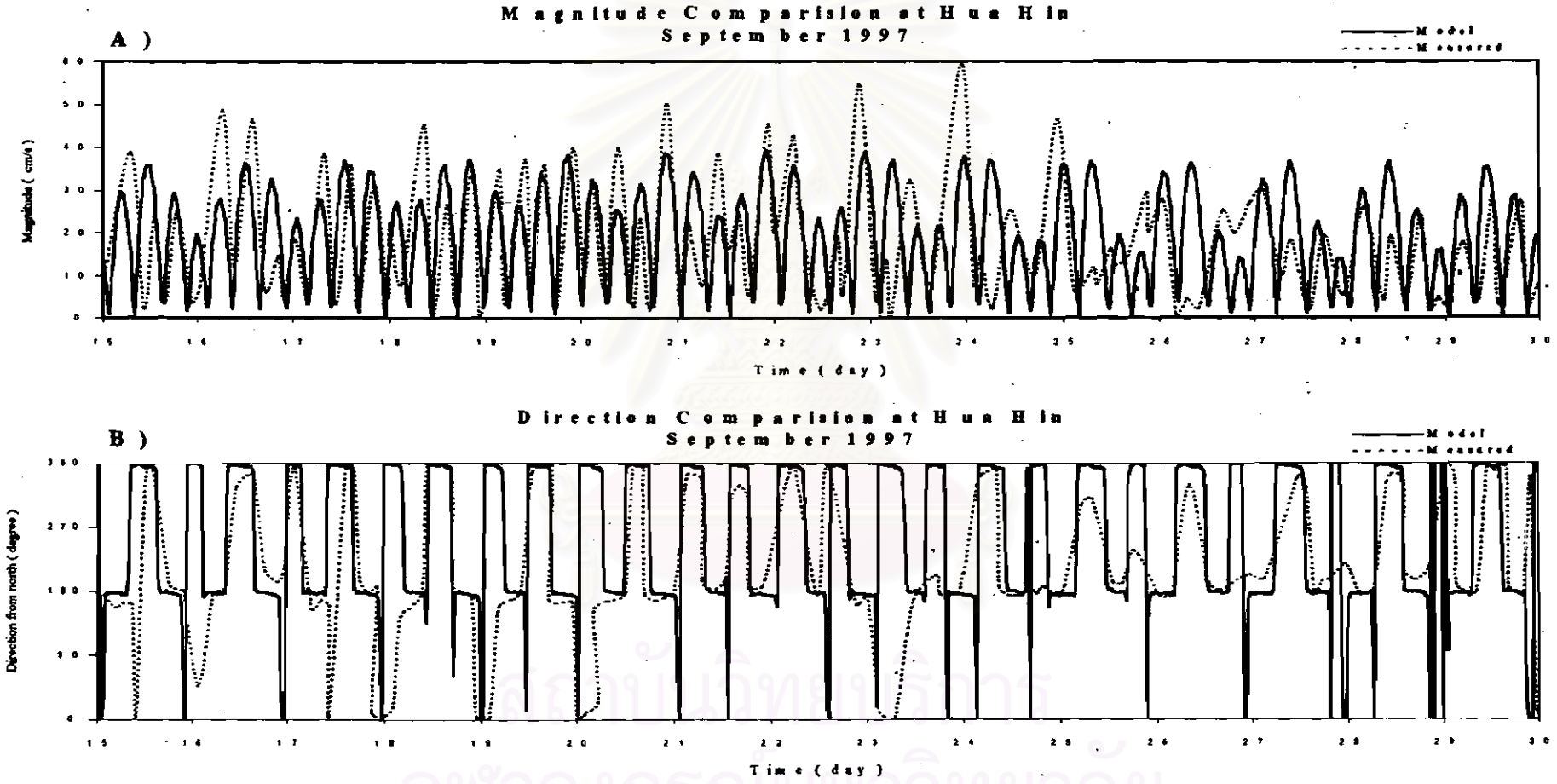


Figure 49. Comparison of measured and computed current at Hua Hin in September 1997

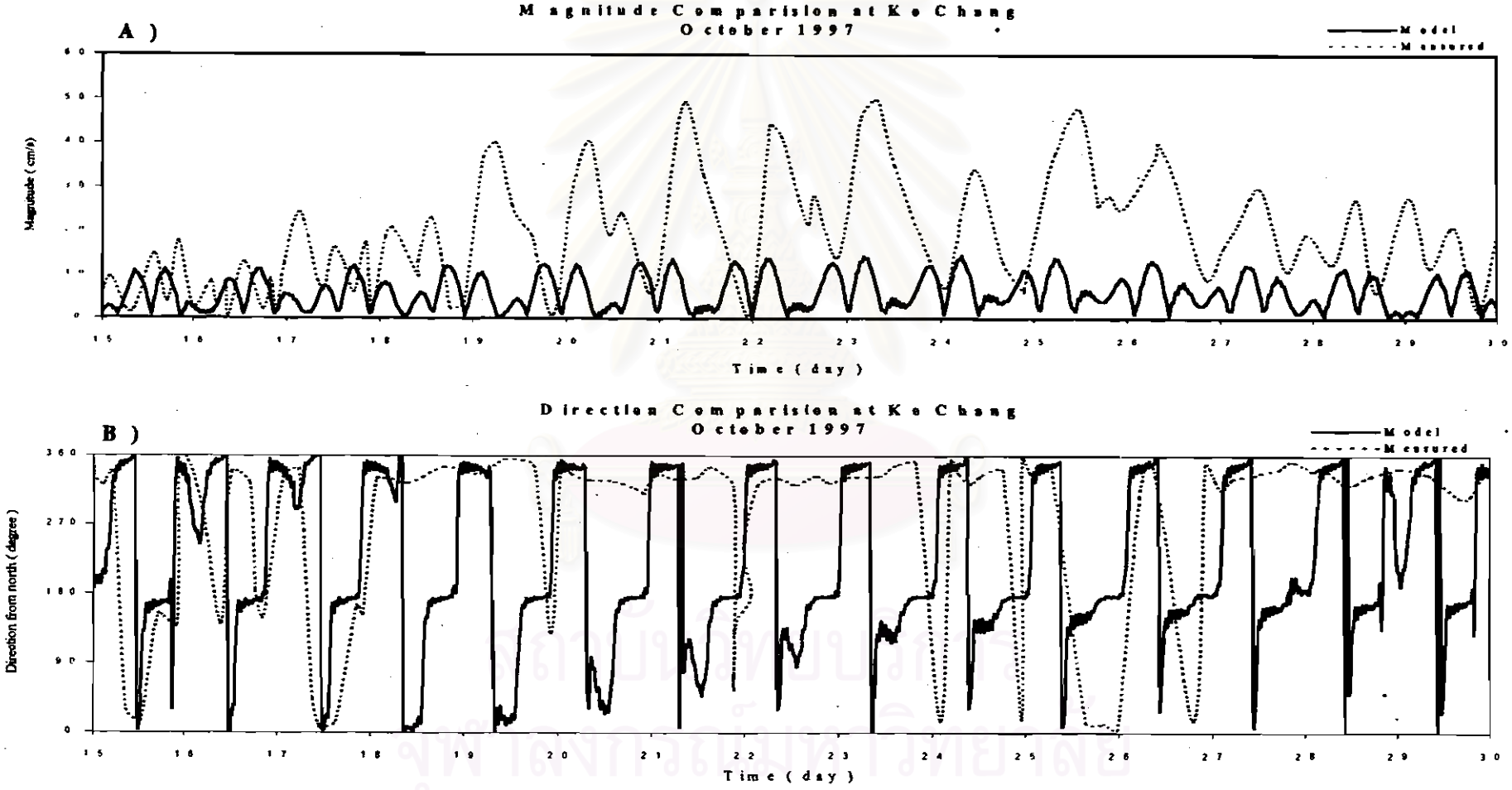


Figure 50. Comparison of measured and computed current at Ko Chang in October 1997

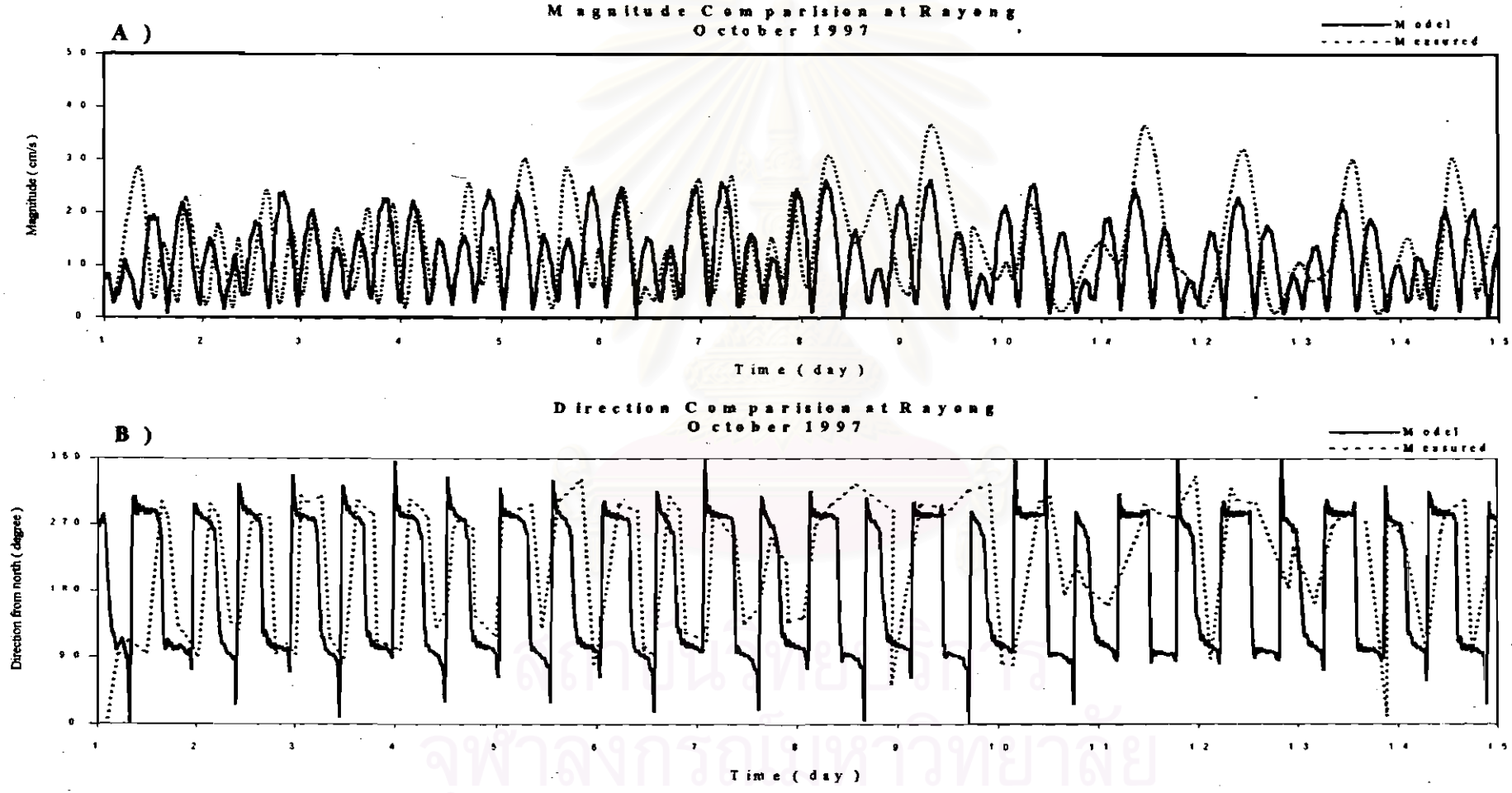


Figure 51. Comparison of measured and computed current at Rayong in October 1997

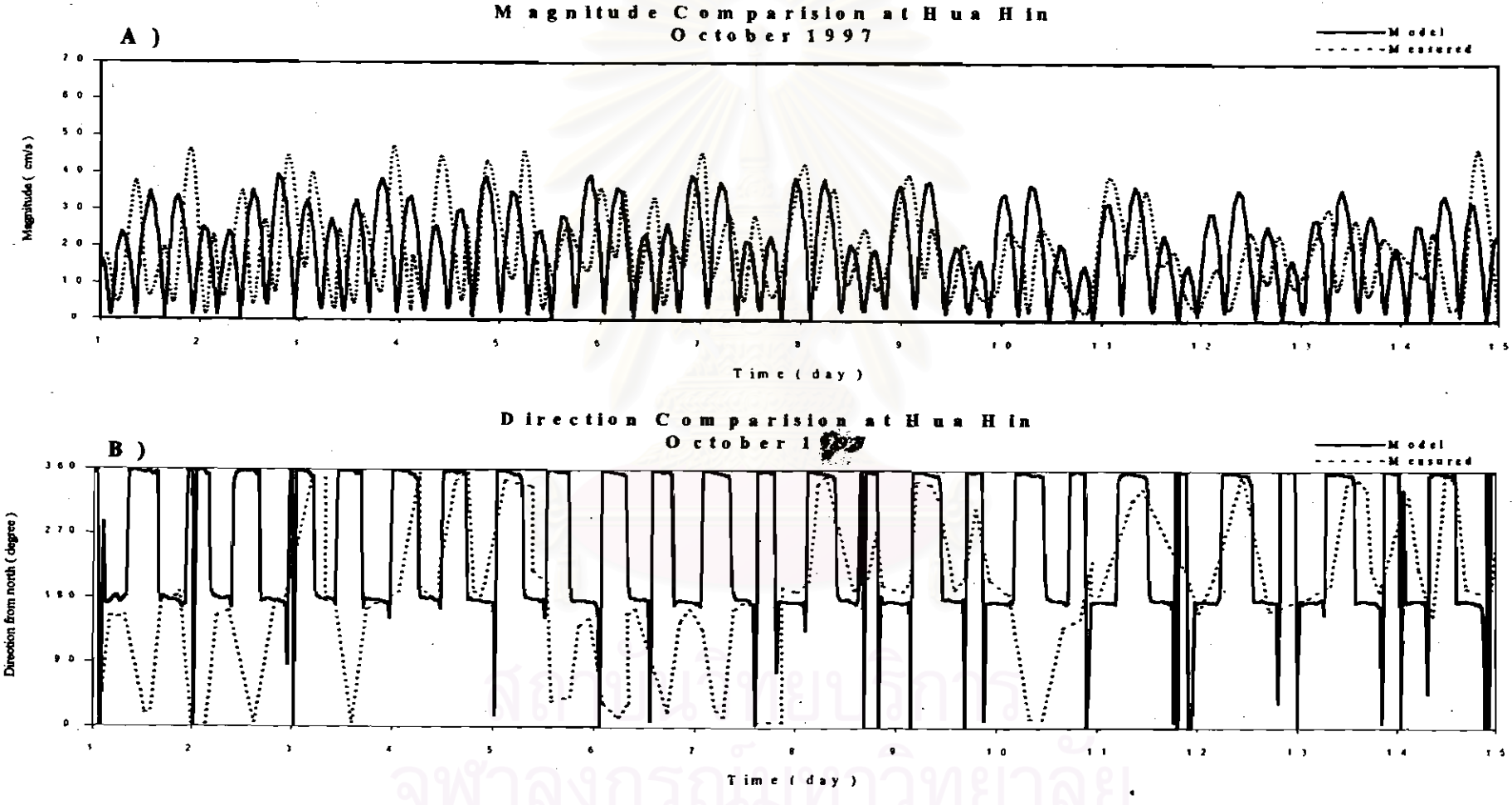


Figure 52. Comparison of measured and computed current at Hua Hin in October 1997

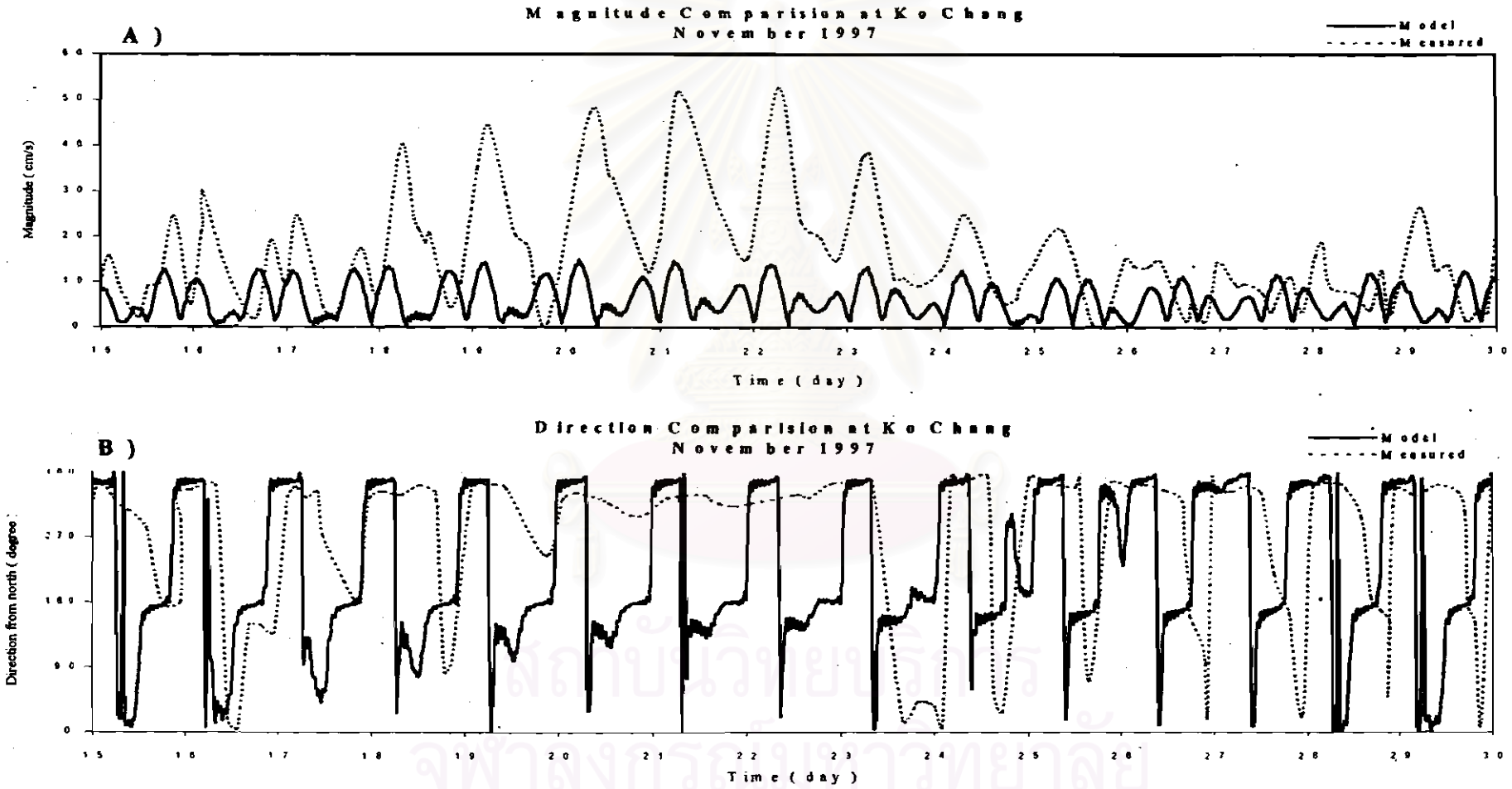


Figure 53. Comparison of measured and computed current at Ko Chang in November 1997

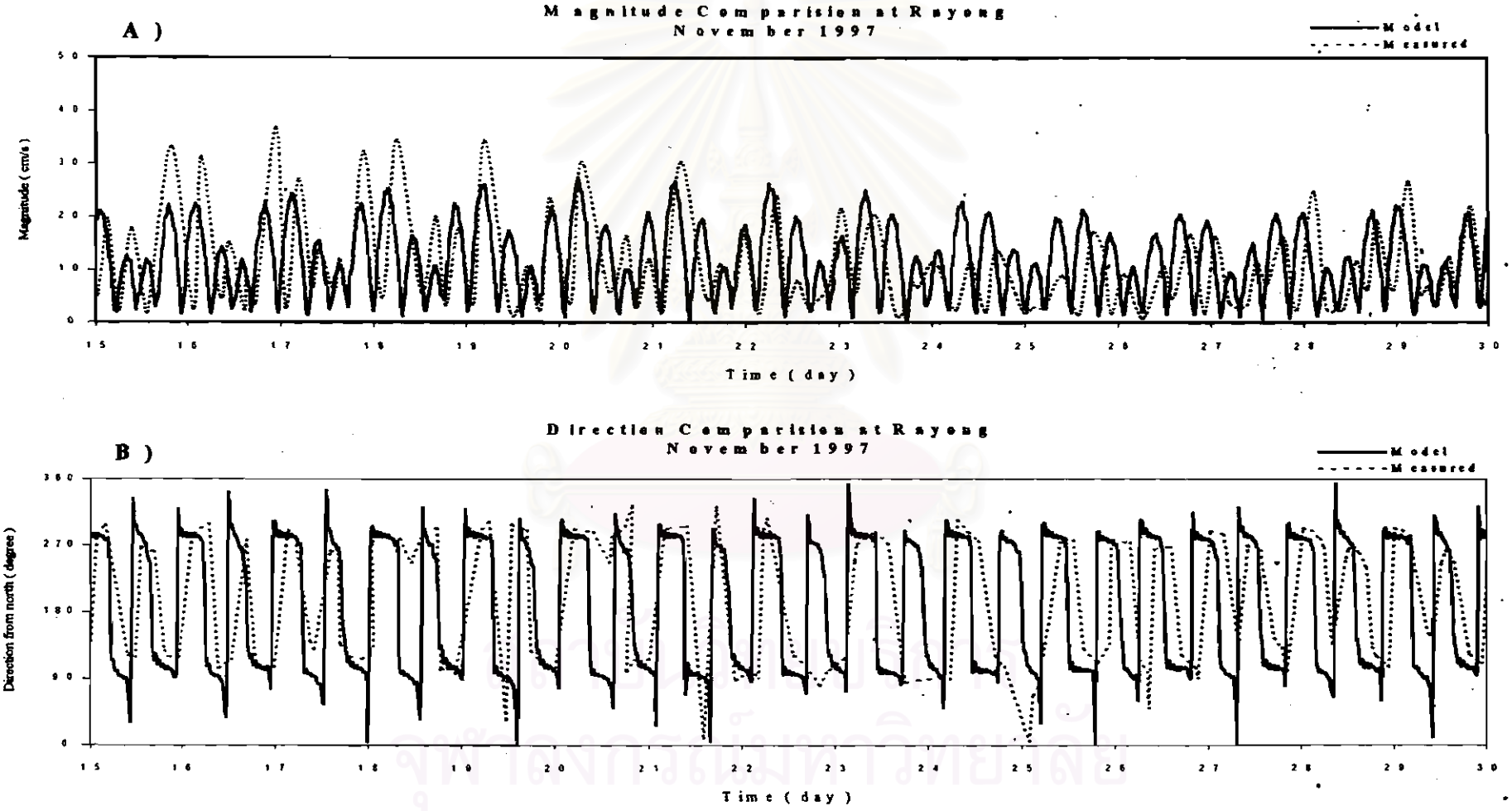


Figure 54. Comparison of measured and computed current at Rayong in November 1997

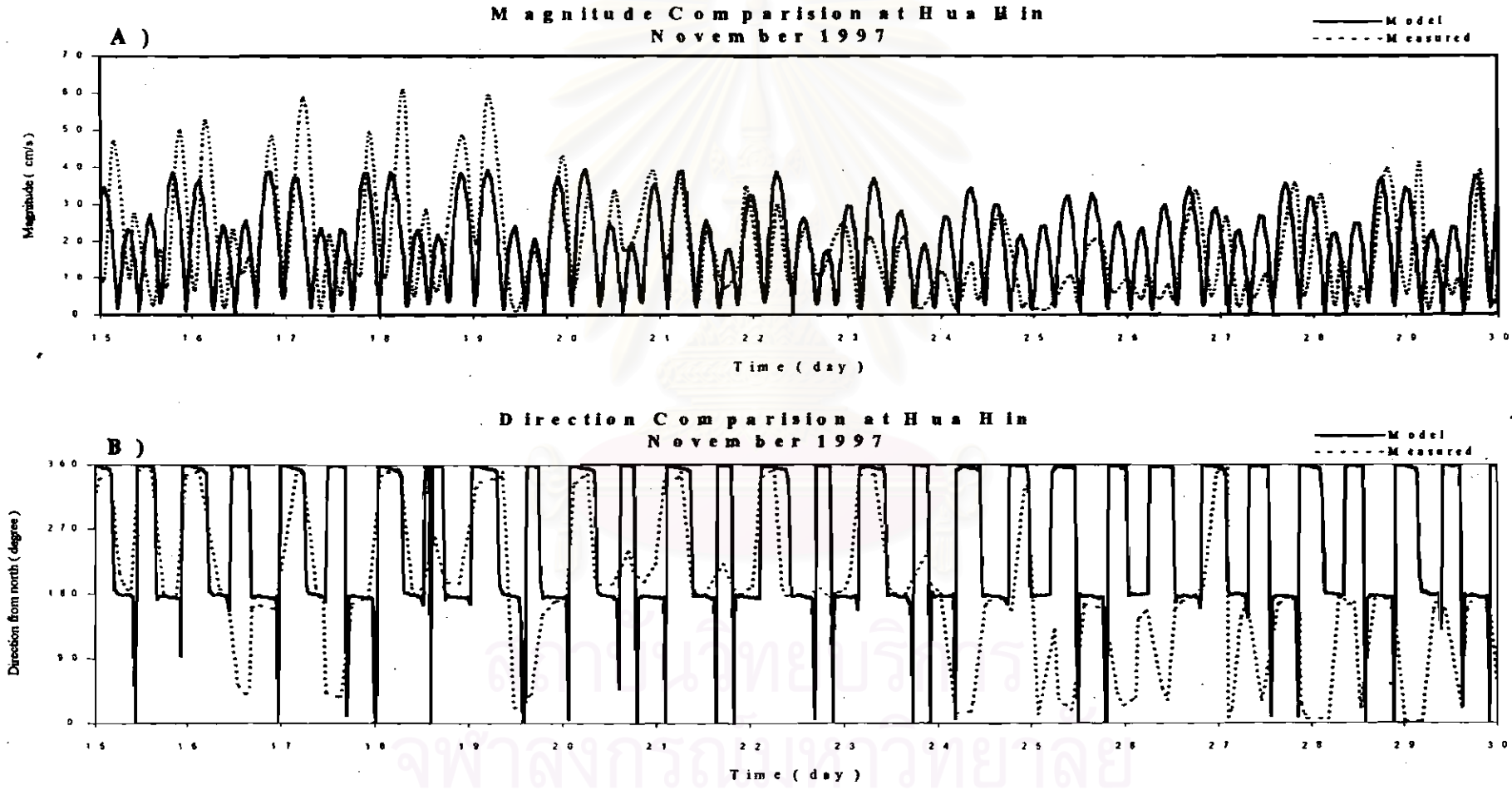


Figure 55. Comparison of measured and computed current at Hua Hin in November 1997

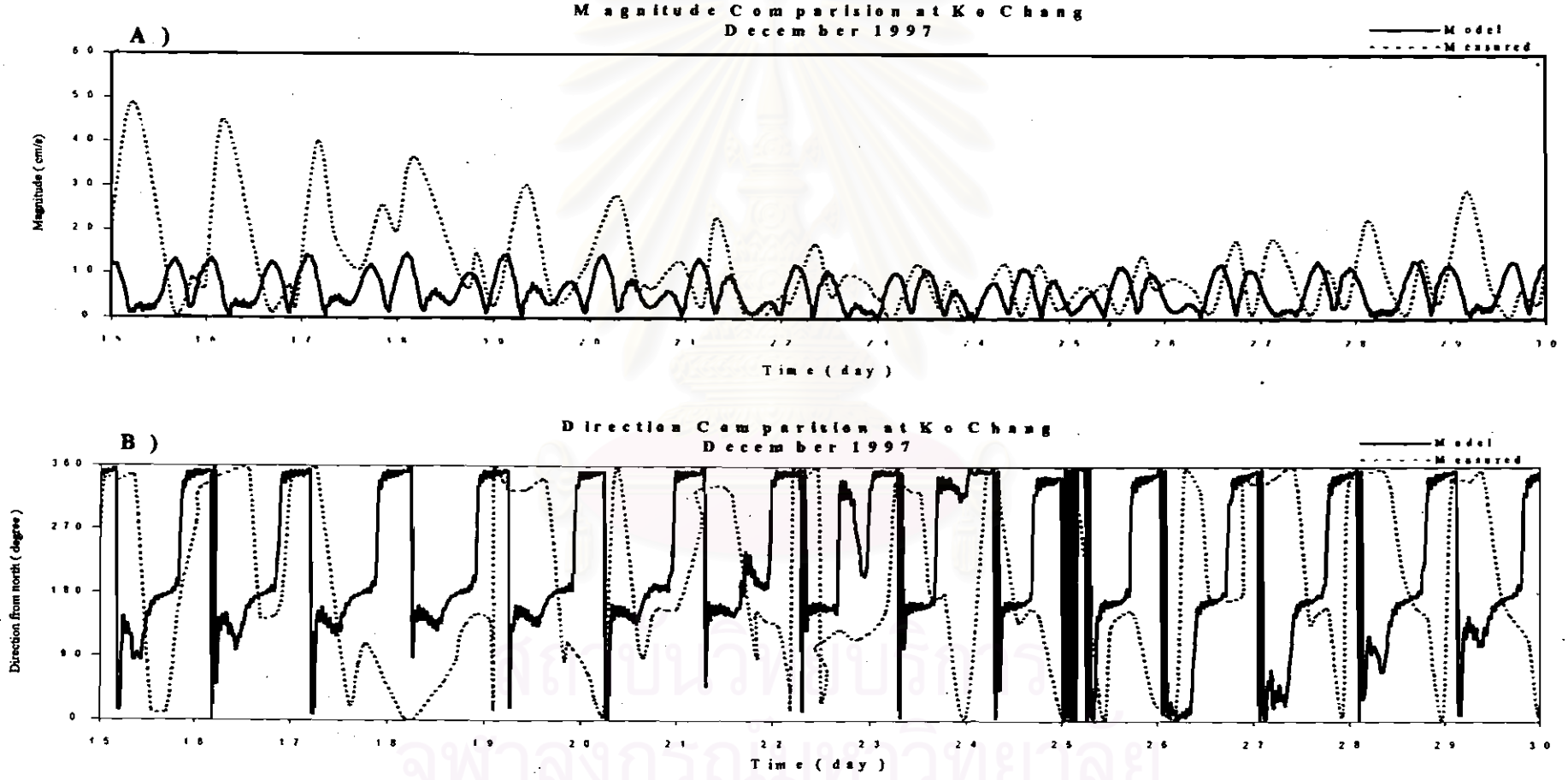


Figure 56. Comparison of measured and computed current at Ko Chang in December 1997

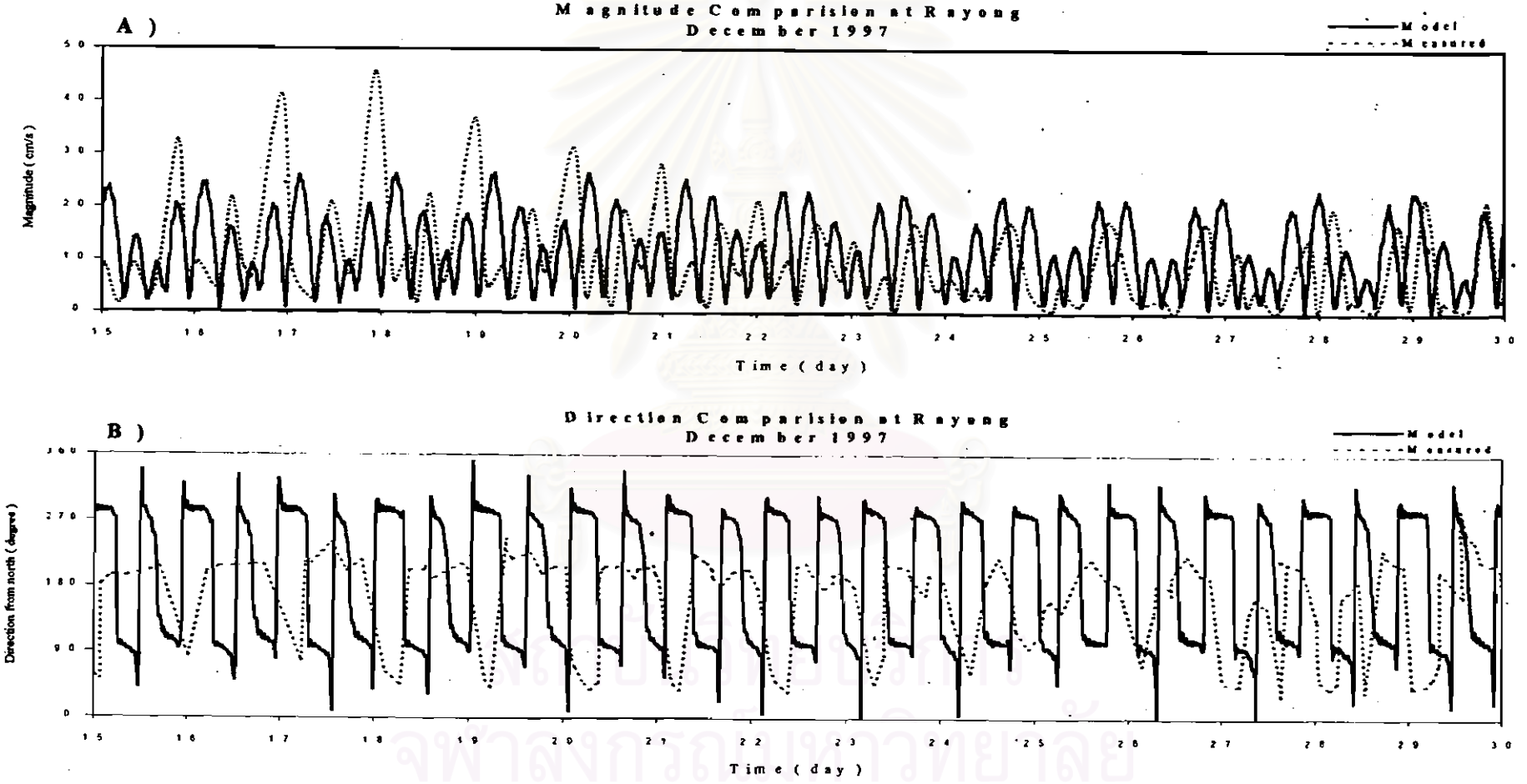


Figure 57. Comparison of measured and computed current at Rayong in December 1997

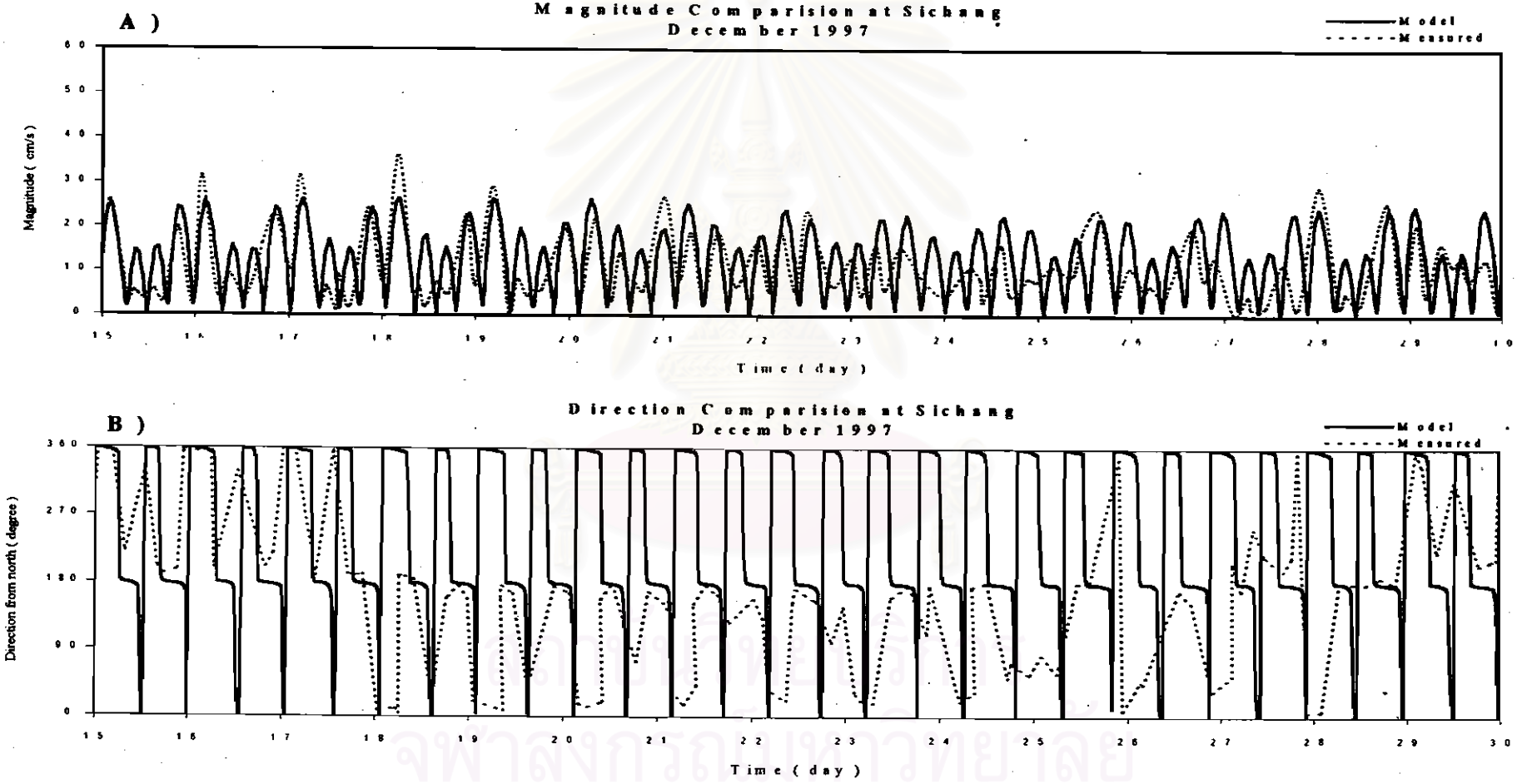


Figure 58. Comparison of measured and computed current at Ko Sichang in December 1997

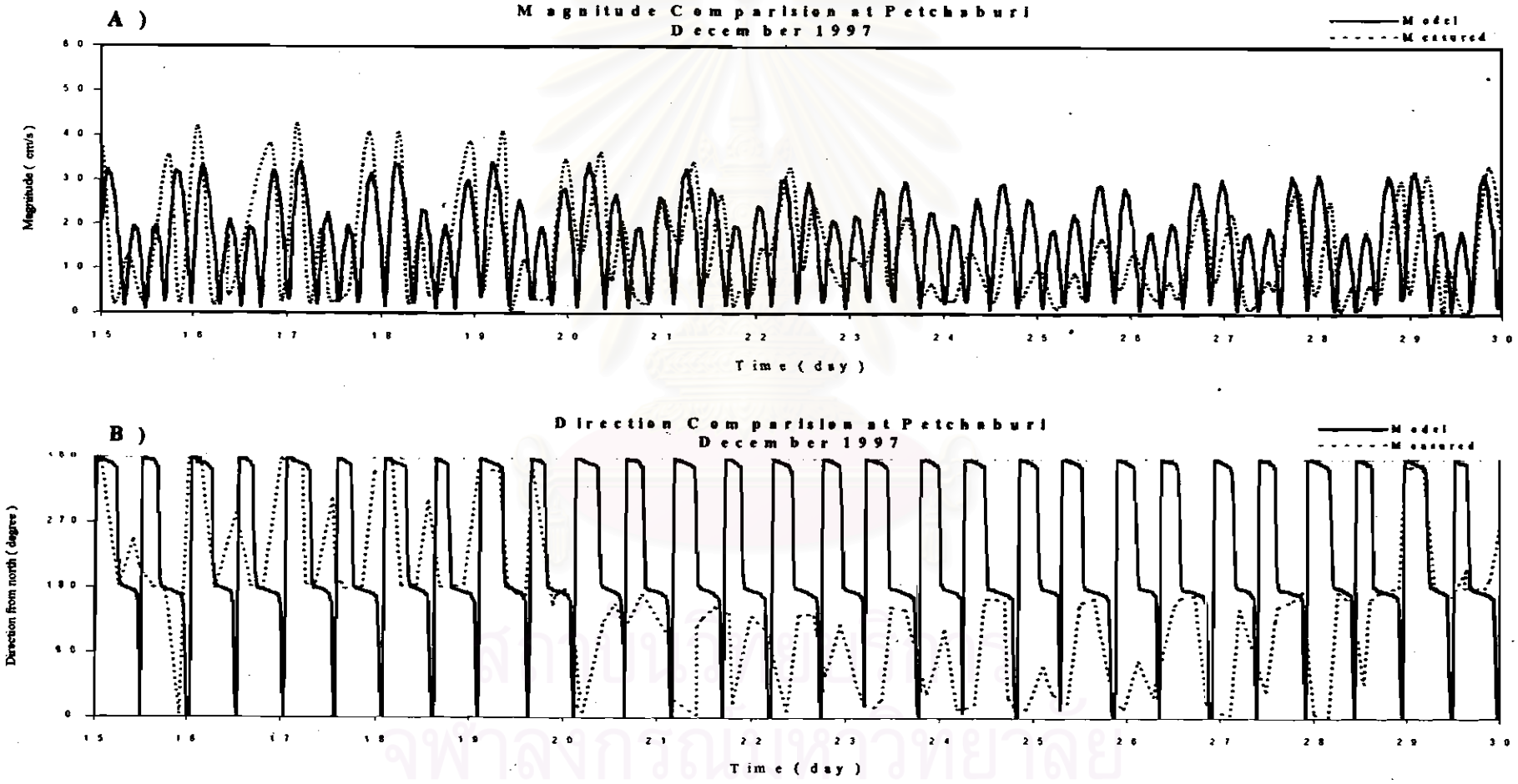


Figure 59. Comparison of measured and computed current at Petchaburi in December 1997

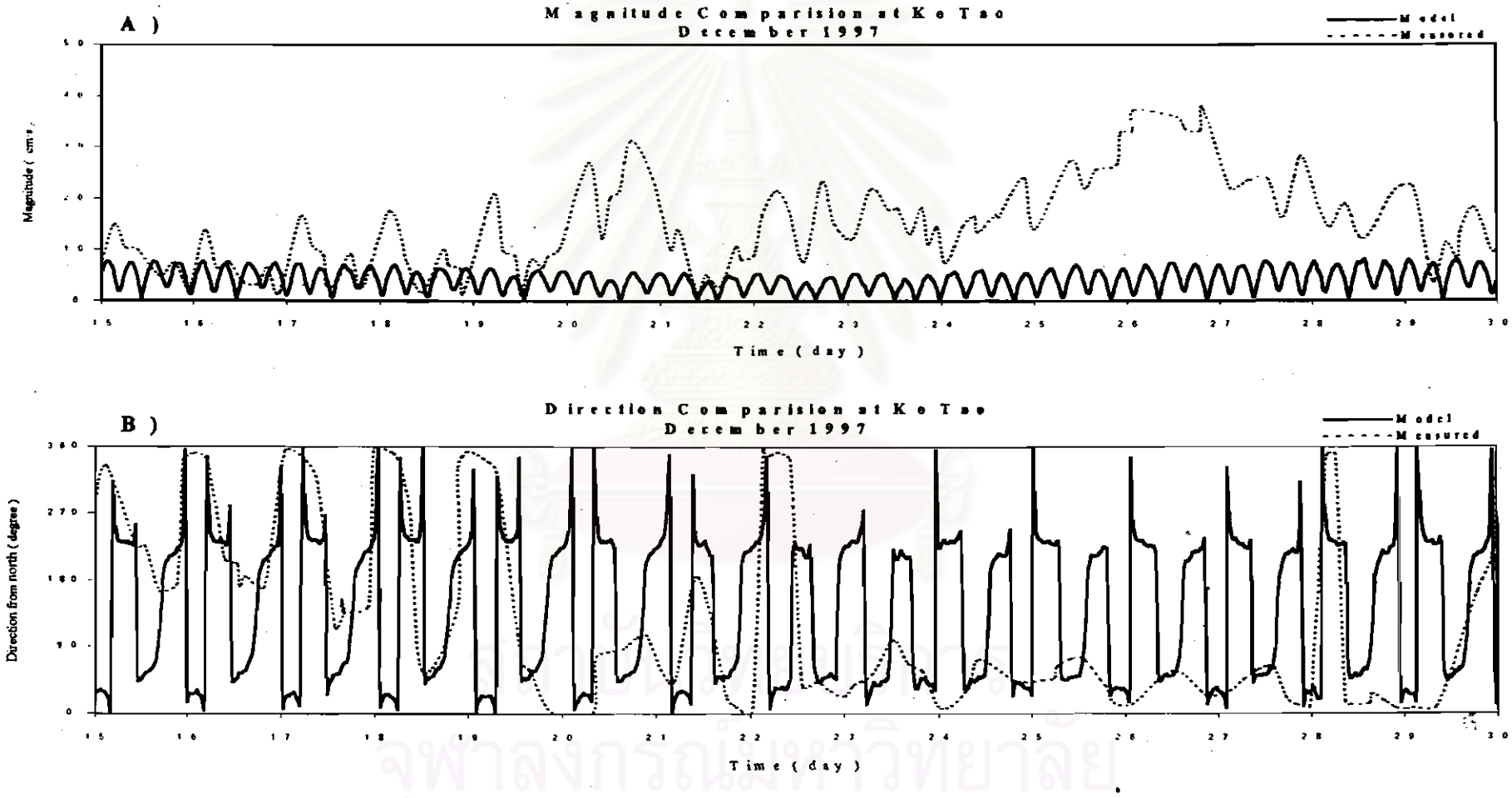


Figure 60. Comparison of measure and computed current at Ko Tao in December 1997

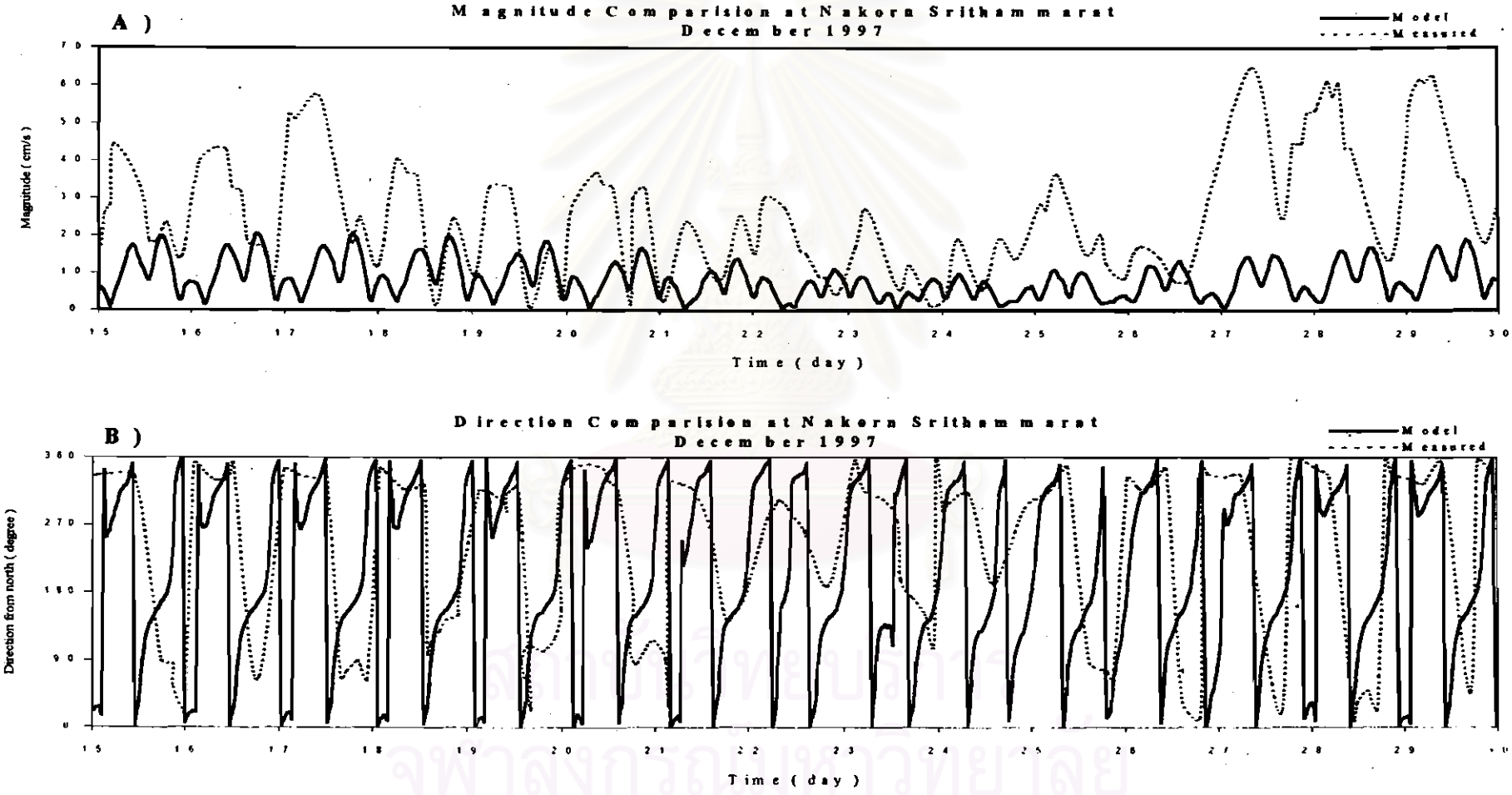


Figure 61. Comparison of measured and computed current at Nakorn Srithammarat in December 1997

To illustrate the relationship between measured and computed current, the relation charts were shown in Figure 62 to 68. In each figure, chart A and chart B show the relation of magnitude and direction respectively. The straight line in each chart is linearly trend line, while r and N mean the values of correlation coefficient and number of sample respectively. The current data at Ko Chang, Rayong, Ko Sichang, Petchaburi, and Hua Hin were from March, April and June because the measured data in these months were complete. However, for Ko Tao and Nakorn Srithammarat, because there are the measured current data only in December, thus just current data in this month was employed.

For the relation of magnitude, the correlation coefficient (r) from each station ordered from maximum to minimum were 8.5777, 7.3503, 4.8651, 4.5970, 2.1823, 1.7275, and –3.1553 at Ko Sichang, Hua Hin, Petchaburi, Rayong, Ko Tao, Nakorn Srethammarat, and Ko Chang respectively. And for the relation of direction, the correlation coefficient (r) ordered from maximum to minimum were 0.8339, 0.7522, 0.7257, 0.5792, 0.4724, 0.2936, and –0.0414 at Ko Sichang, Hua Hin, Petchaburi, Rayong, Nakorn Srithammarat, Ko Tao, and Ko Chang respectively.

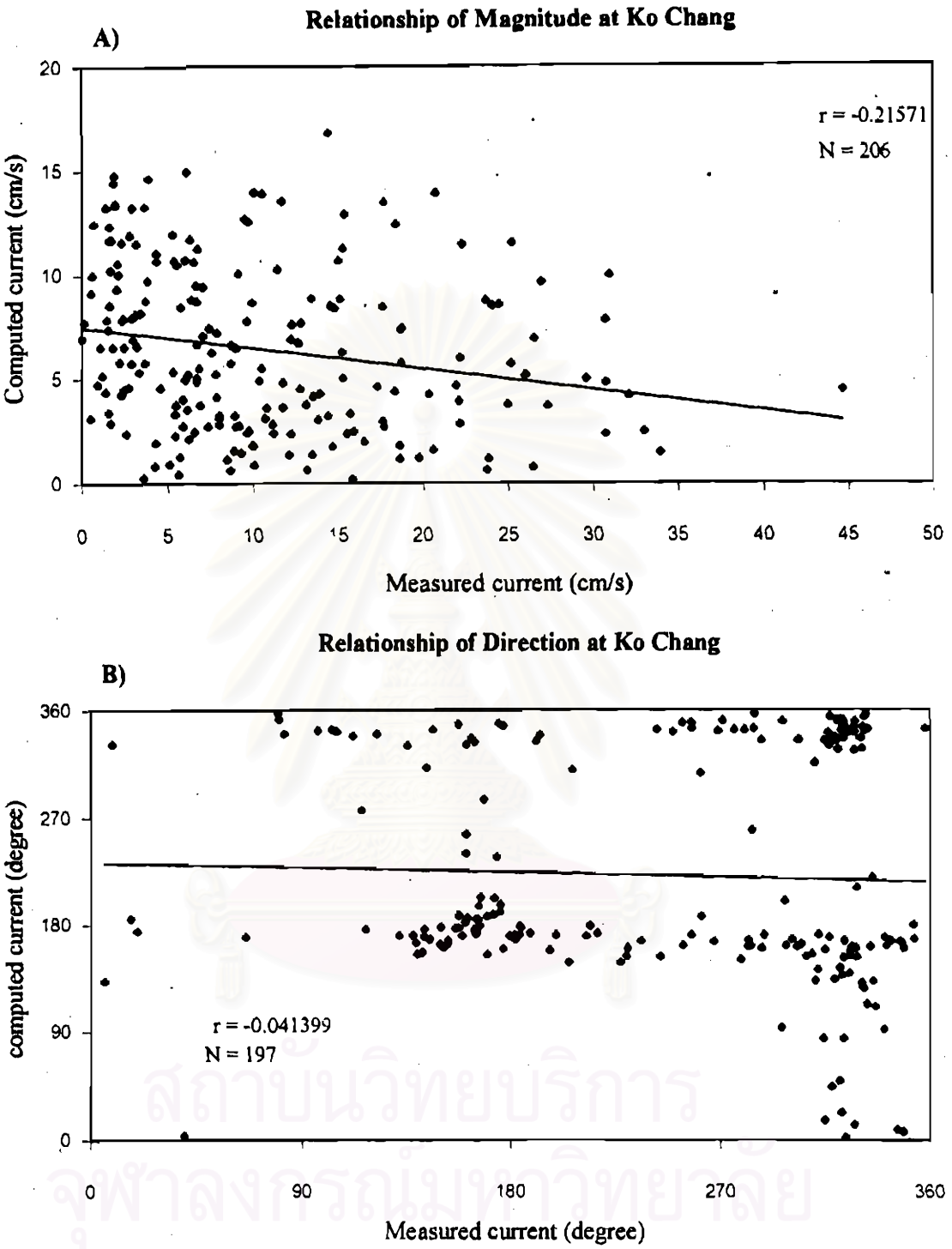


Figure 62. Relationship between measured and computed current at Ko Chang.

A) : Magnitude

B) : Direction.

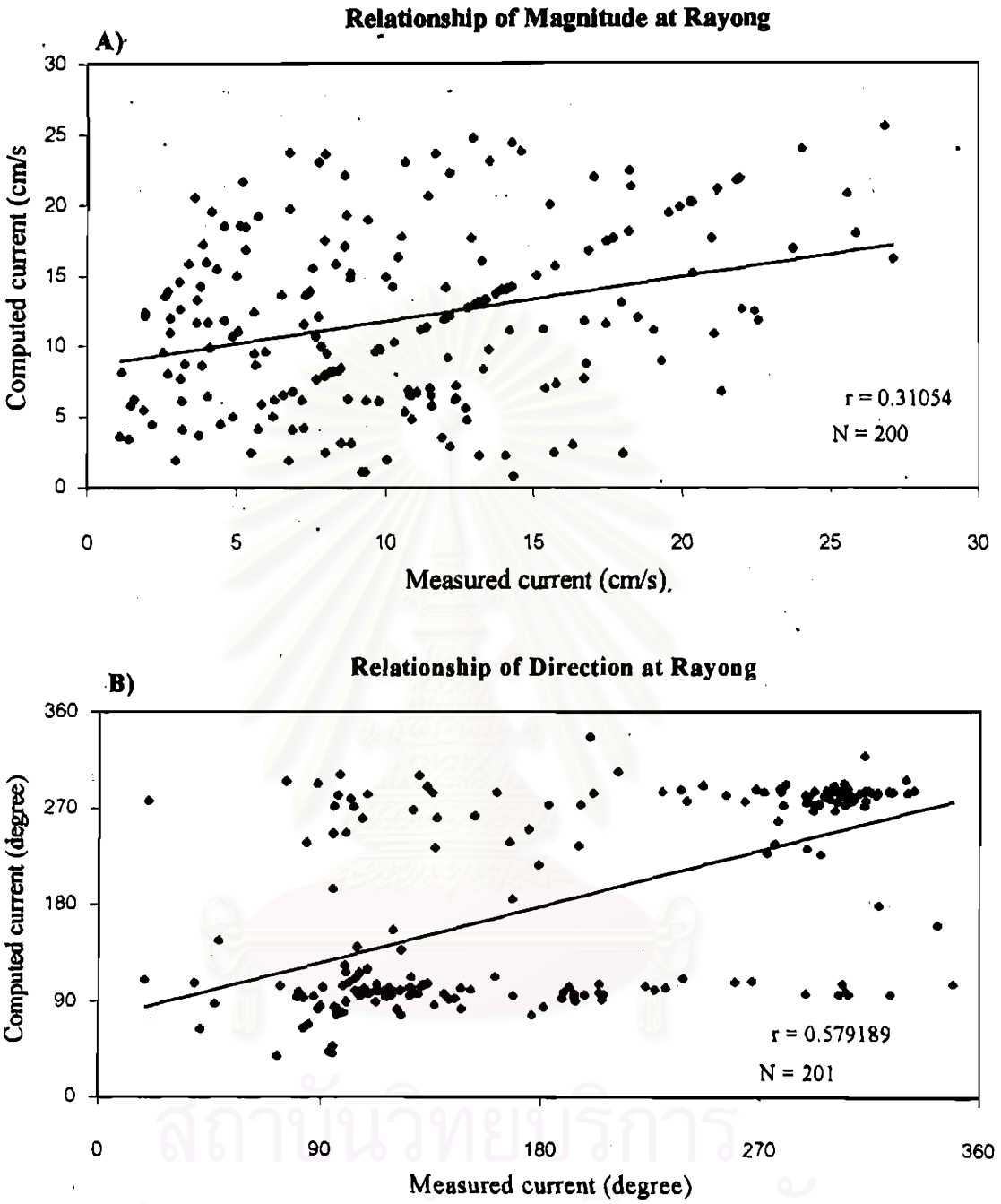


Figure 63. Relationship between measured and computed current at Rayong.

A) : Magnitude

B) : Direction.

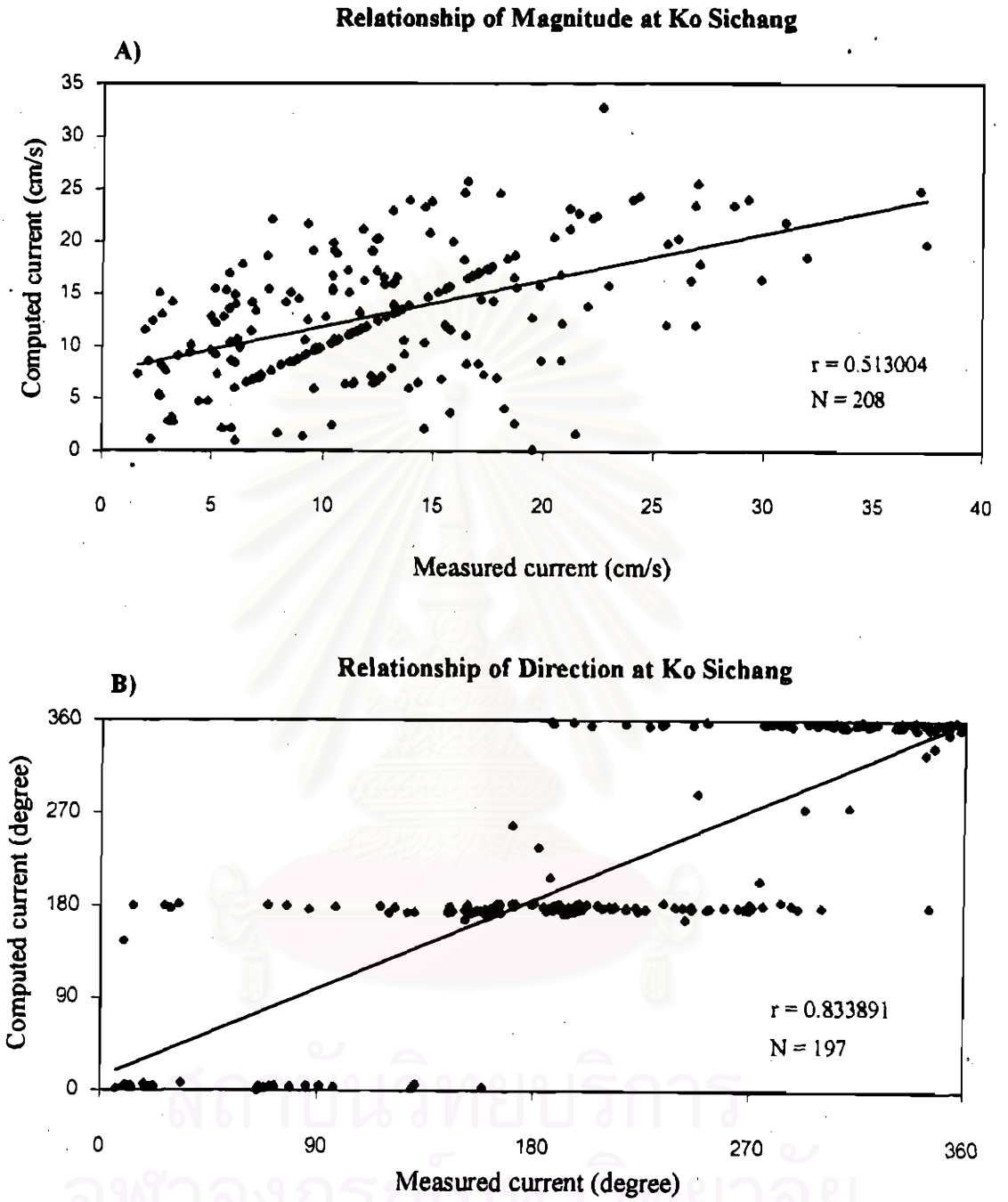


Figure 64. Relationship between measured and computed current at Ko Sichang.

A) : Magnitude

B) : Direction.

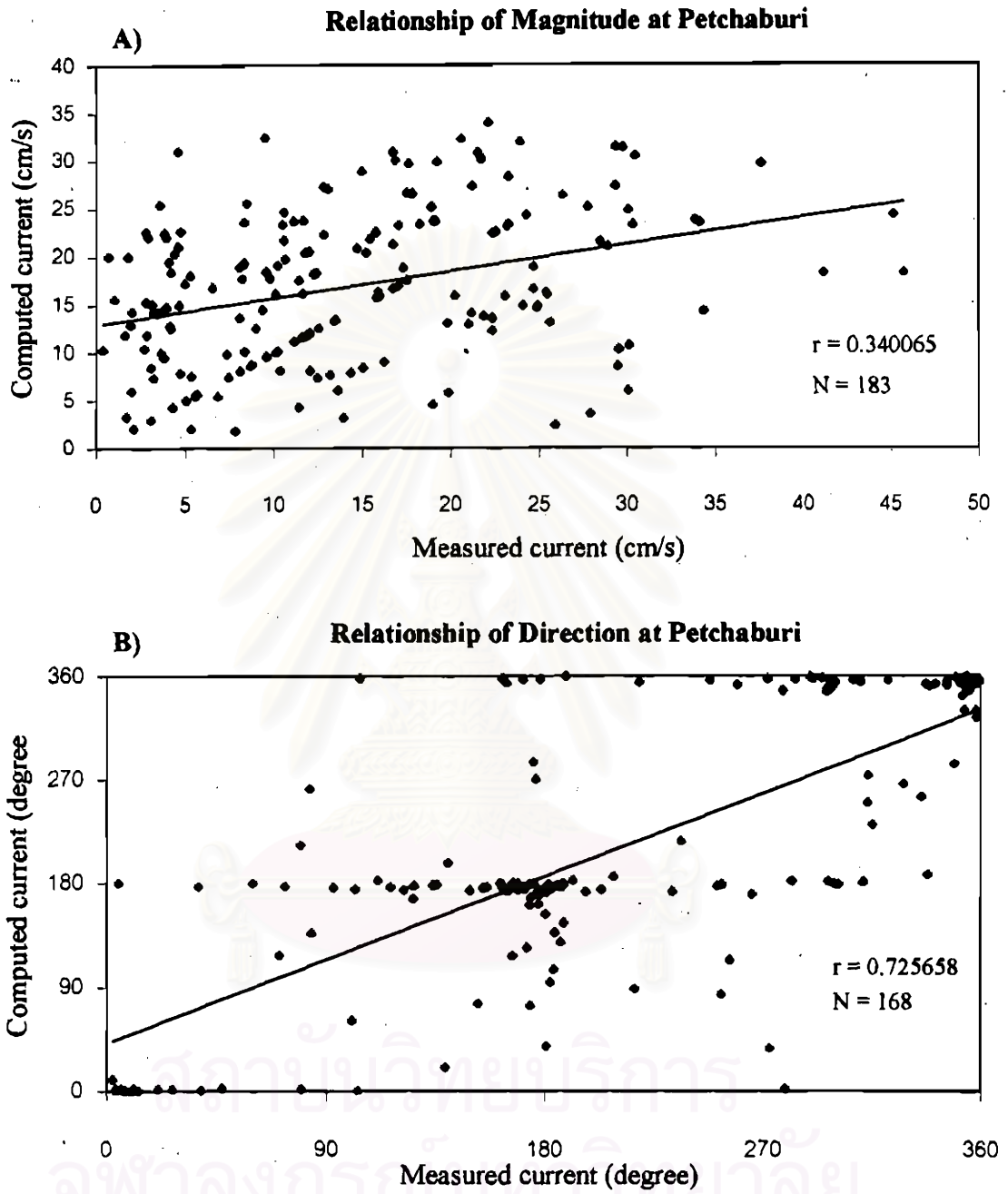
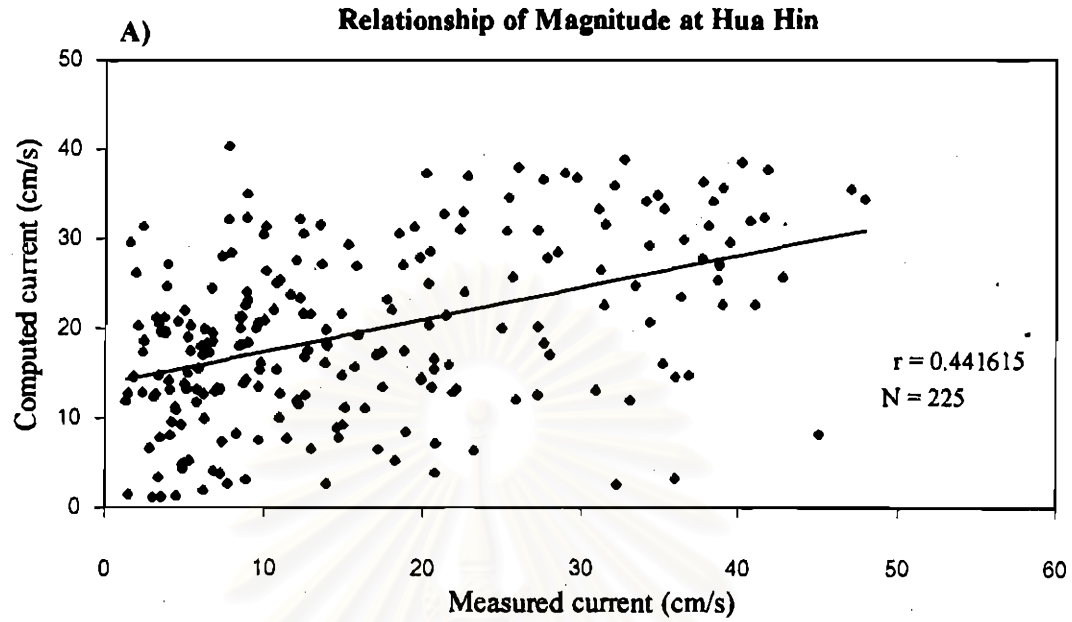


Figure 65. Relationship between measured and computed current at Petchaburi.

A) : Magnitude

B) : Direction.



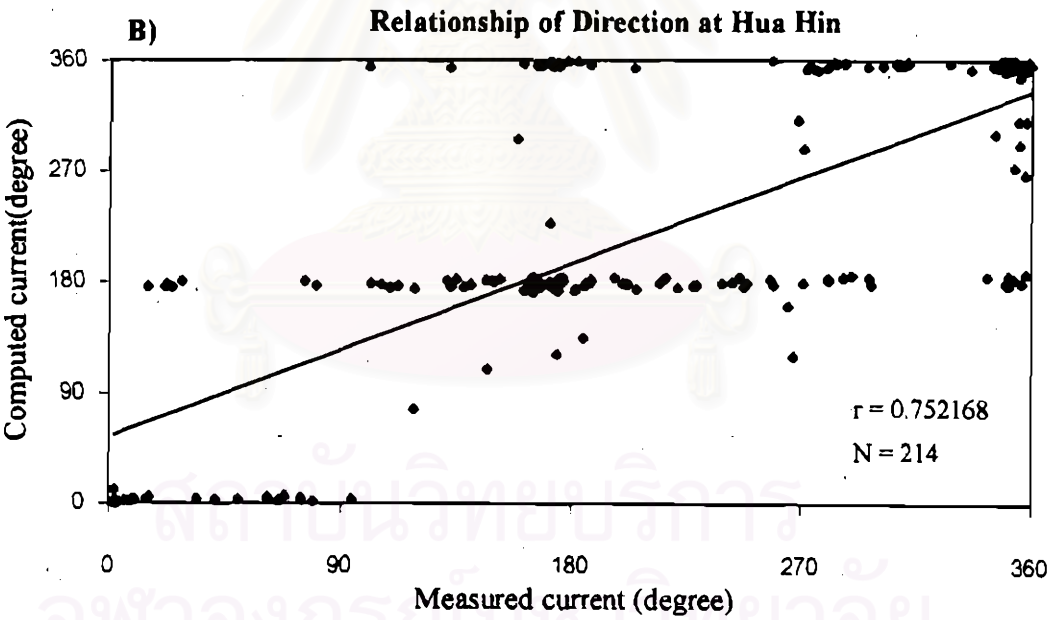


Figure 66. Relationship between measured and computed current at Hua Hin.

A) : Magnitude

B) : Direction.

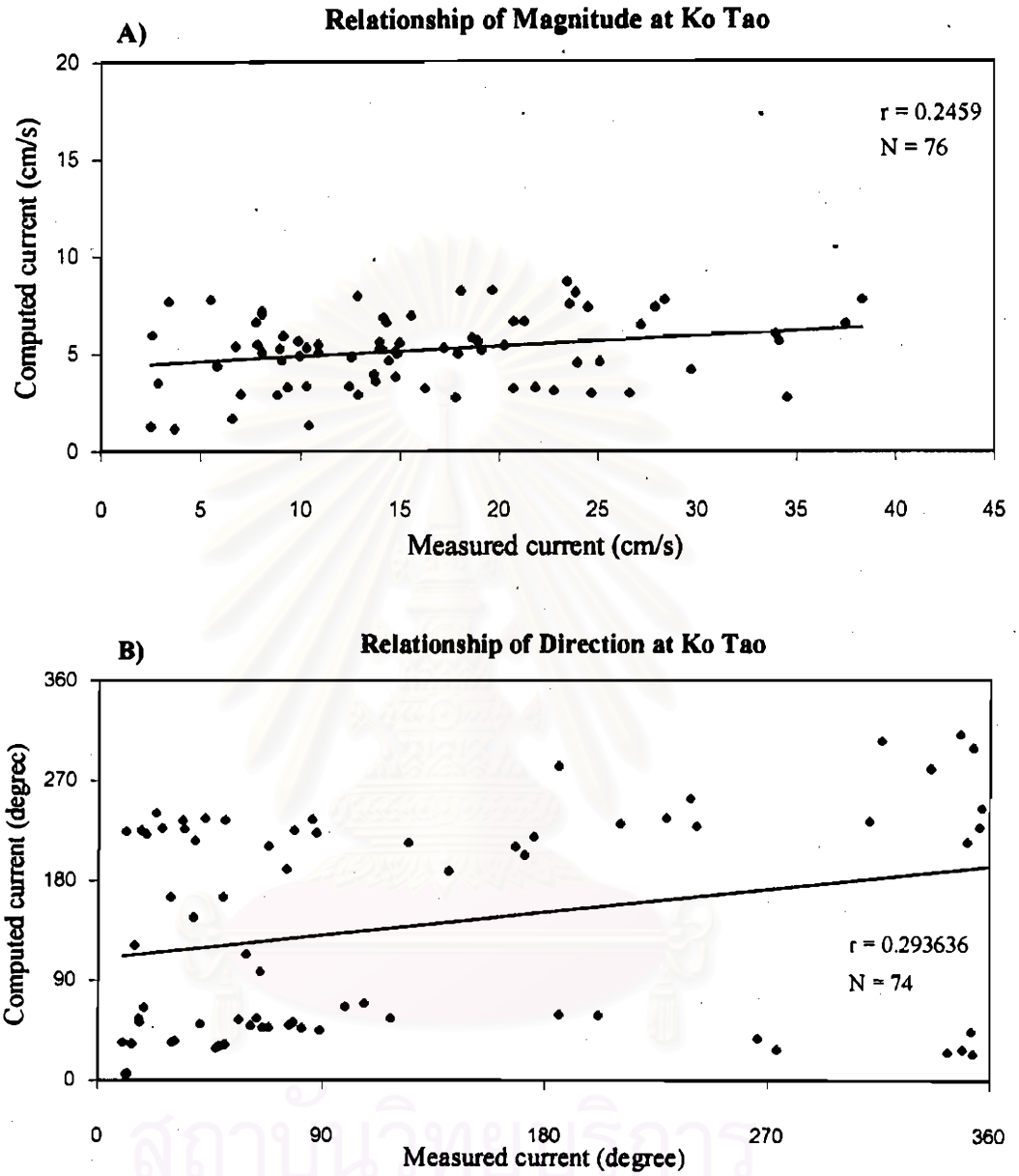


Figure 67. Relationship between measured and computed current at Ko Tao.

A) : Magnitude

B) : Direction.

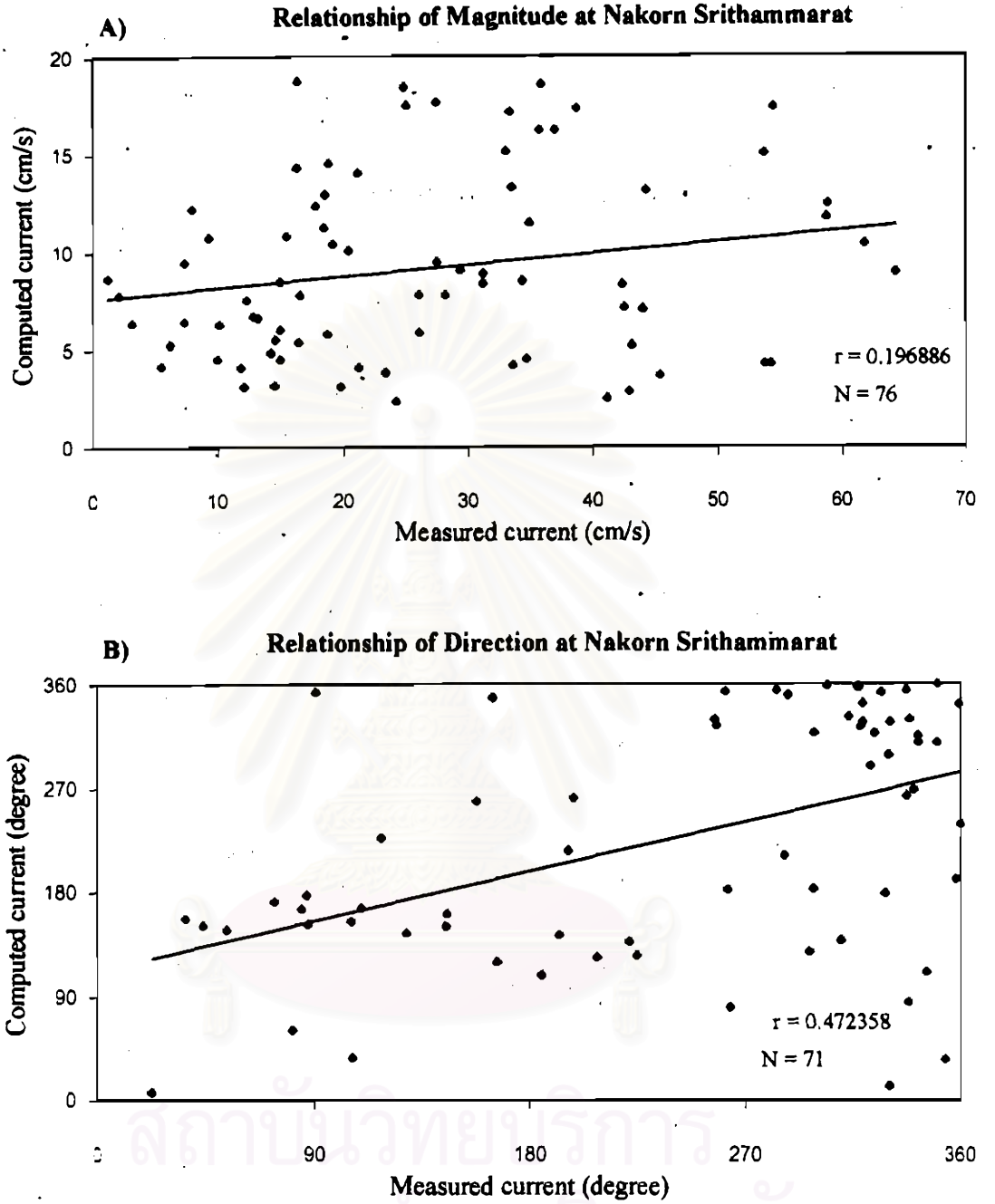


Figure 68. Relationship between measured and computed current at Nakorn Srithammarat.

A) : Magnitude

B) : Direction.

3. The circulation patterns

In this section, to find out the long-term circulation, the current for a long time at least more than the period of tidal cycle (around 15 days) would be summed and averaged. Thus, the monthly-mean current vector fields were presented. Figures 69 to 80 show the circulation patterns in each month of the year 1997. The arrow in the chart represents the depth-averaged current in the middle of 6×6 degrees grid area. The results showed the circulation pattern were different from month to month and could be described as follow.

From January to September, the current flowed in the Gulf in the southern part and flowed out in the northern part, but from October to December, the current flowed in and out in the opposite direction. Although, there was the same direction of flow into the Gulf, the circulation pattern inner the Gulf was different.

In January, there is a big gyre of clockwise circulation at the low-middle part of the Gulf and a small counter clockwise gyre at the upper Gulf. The patterns from February to May shows that the current flow to northward along the western part of the middle Gulf, and eastward at the upper part of the upper Gulf. The eddy appears in May in an area above the island in the western.

The complication of flow is illustrated in June, July, and August. There are a number of eddies and a stronger current than in the other months. A current flows upward from the southern part to the central of the Gulf, then it separates in two ways, westward and eastward. Counter-clockwise eddies appear above the island in the western, at the Southern Gulf, and at the lower part of the Upper Gulf. However, there is a prominent clockwise eddy in the most northern part of the upper Gulf in August.

Many eddies still appear in September and October, but the current is weaker (not more than 1 cm/s). It can be noted that from August to November, the current direction is changing. Focusing in the upper Gulf, the direction of flow at the most northern part changes from eastward in September to westward in November. While the area at northwest of the island in the western, the direction of eddy changes from counter-clockwise to clockwise. The characteristic of the flow along the open boundary shows that there is the current came in at the upper part and go out from the Gulf at the lower part near Malaysia.

A big clockwise gyre was evident again in December like January, but the current pattern was more complication. However, in the upper part of the Central Gulf, the small counter-clockwise gyre appeared.

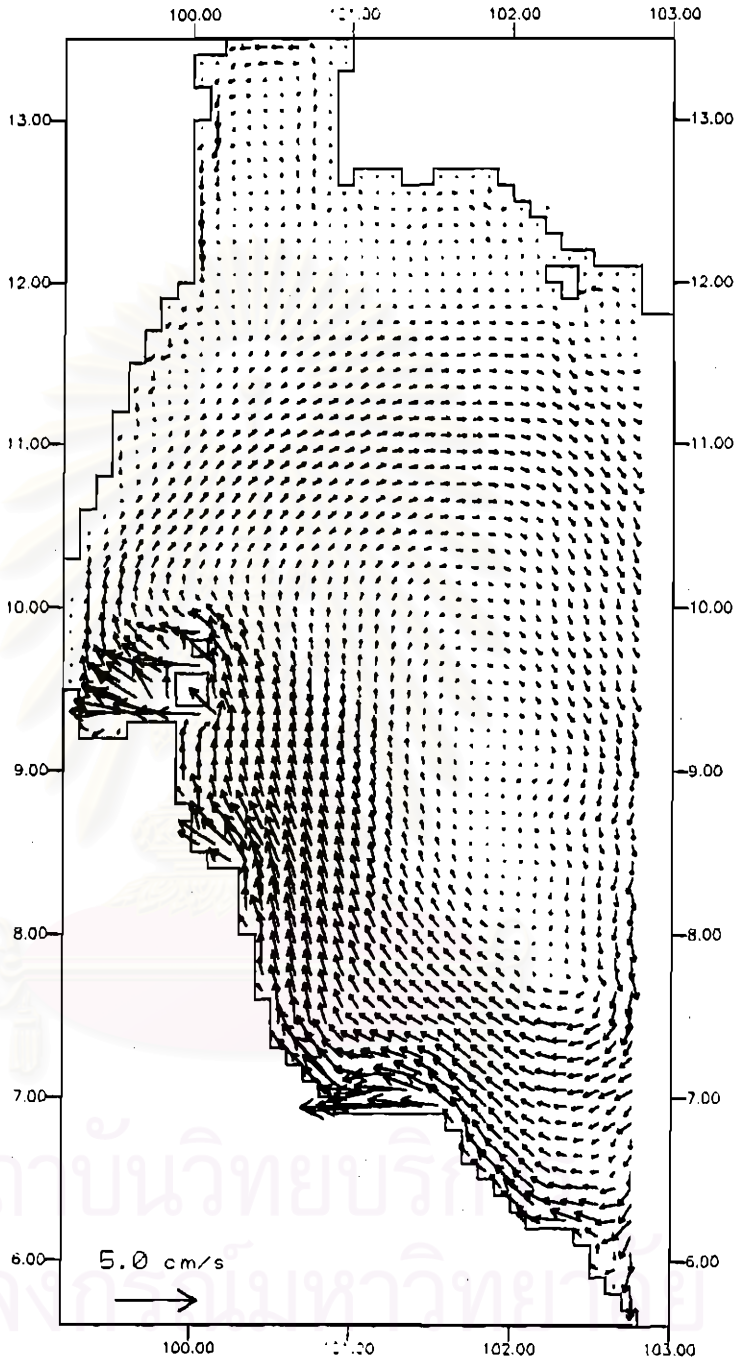


Figure 69. Monthly mean current in January, 1997

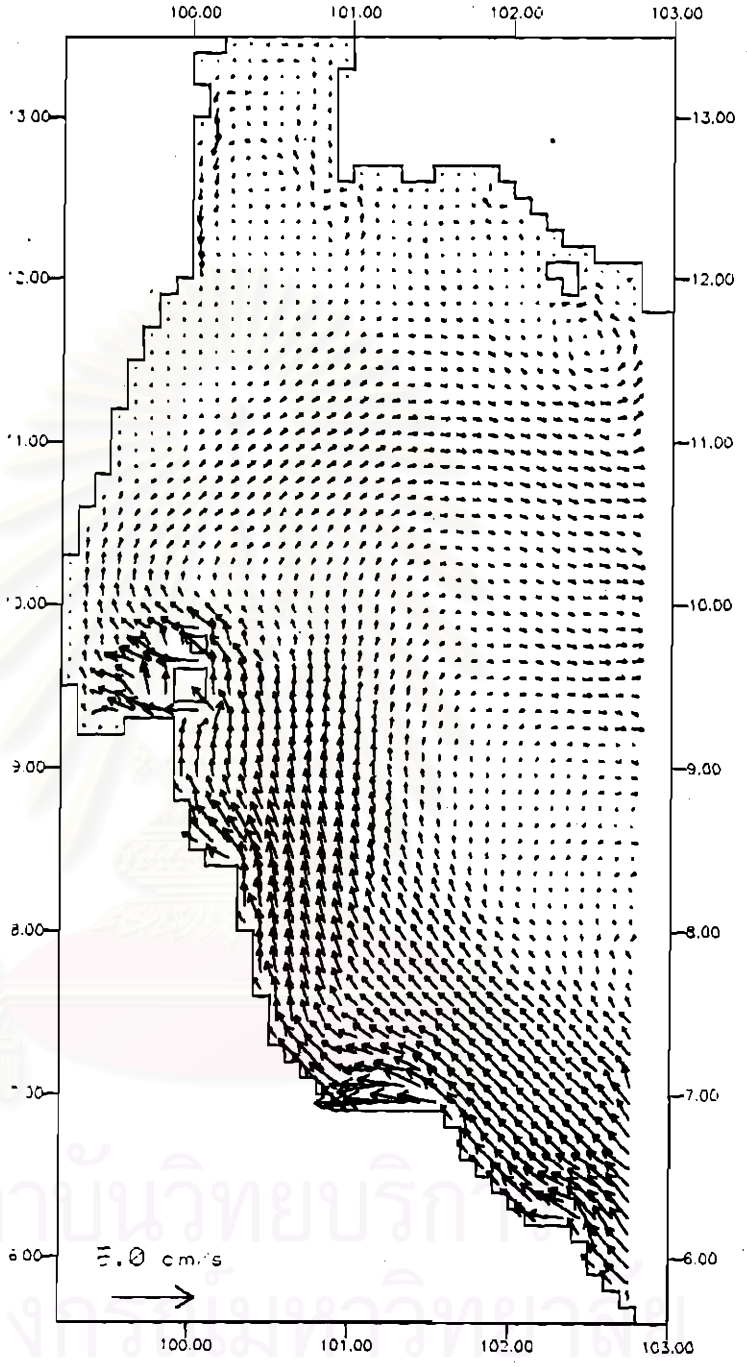


Figure 70. Monthly mean current in February, 1997

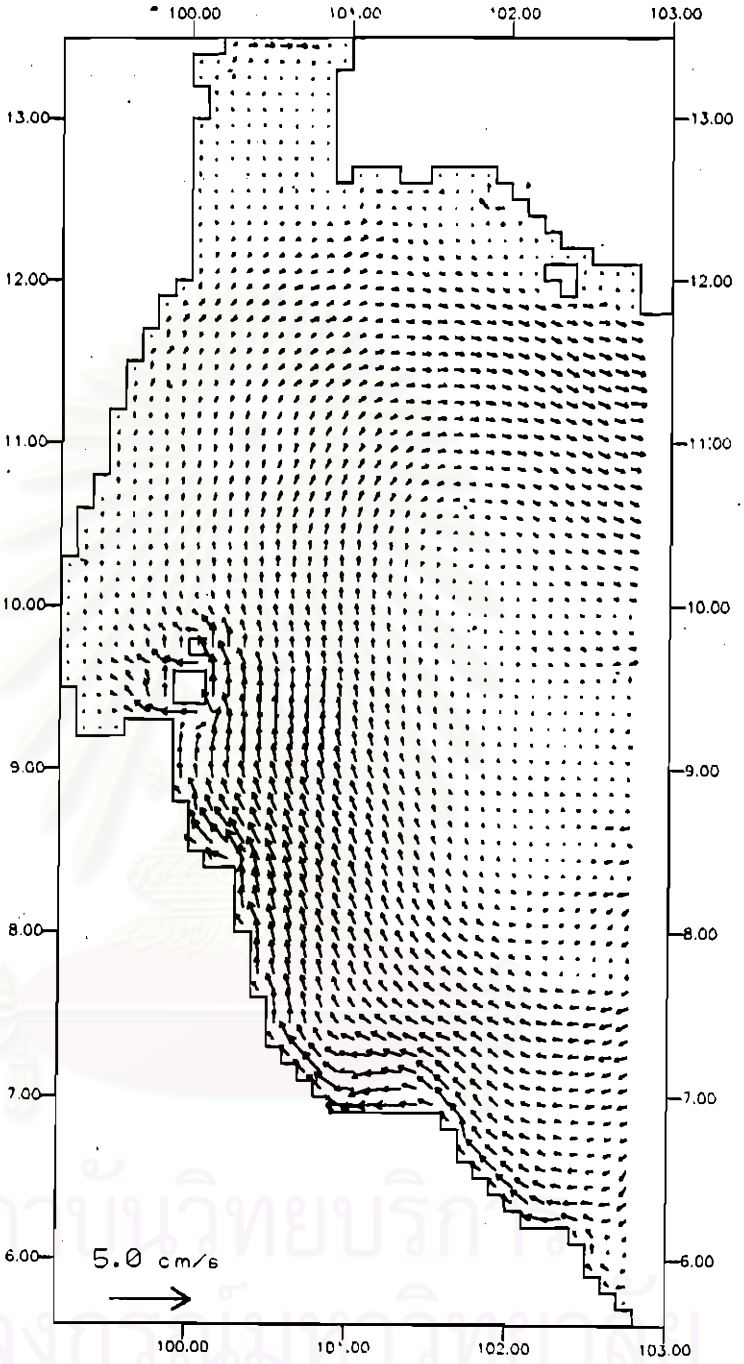


Figure 71. Monthly mean current in March, 1997

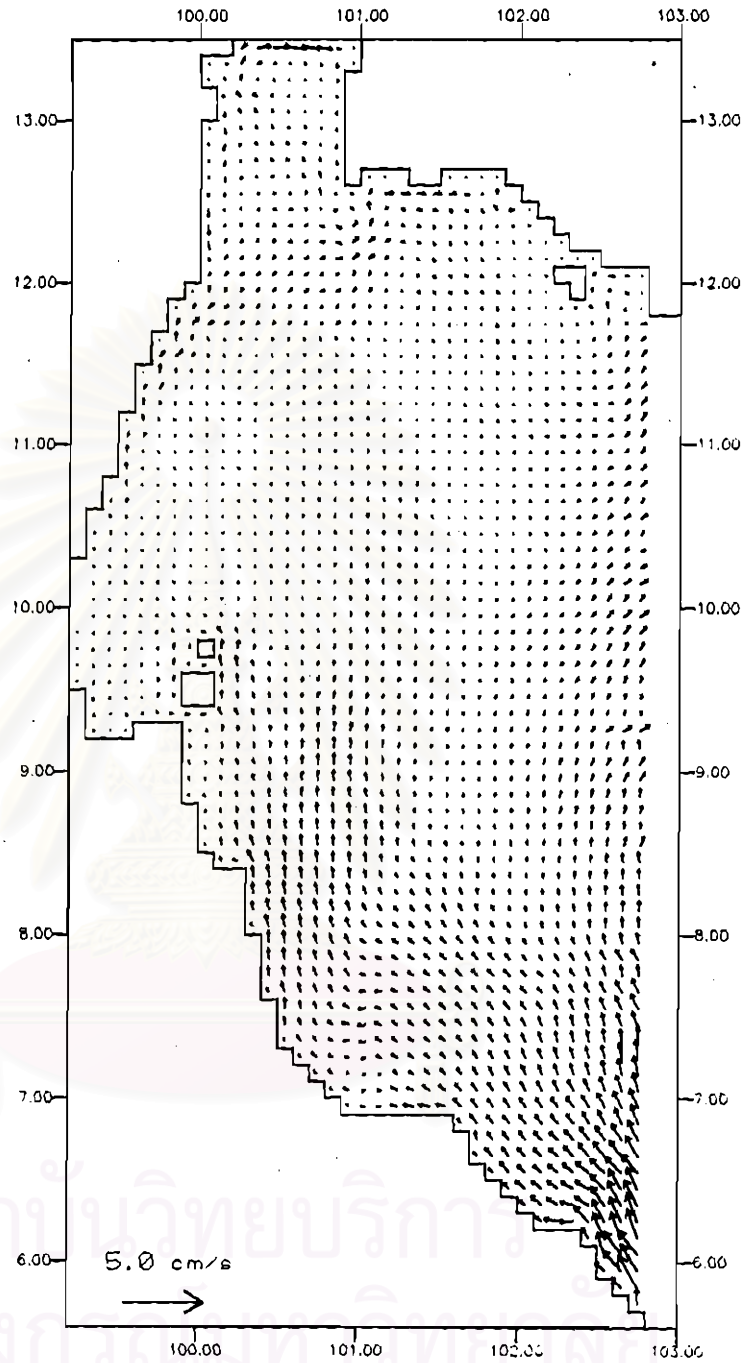


Figure 72. Monthly mean current in April, 1997

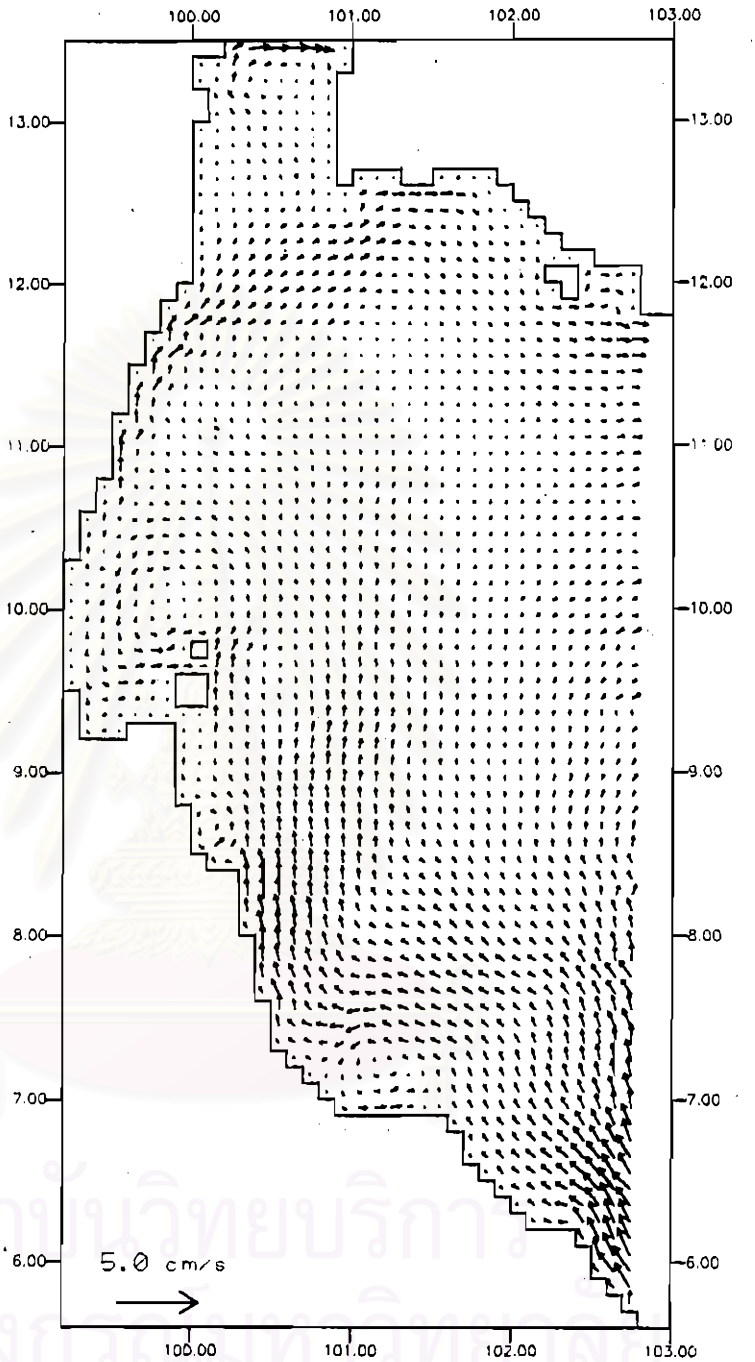


Figure 73. Monthly mean current in May, 1997.

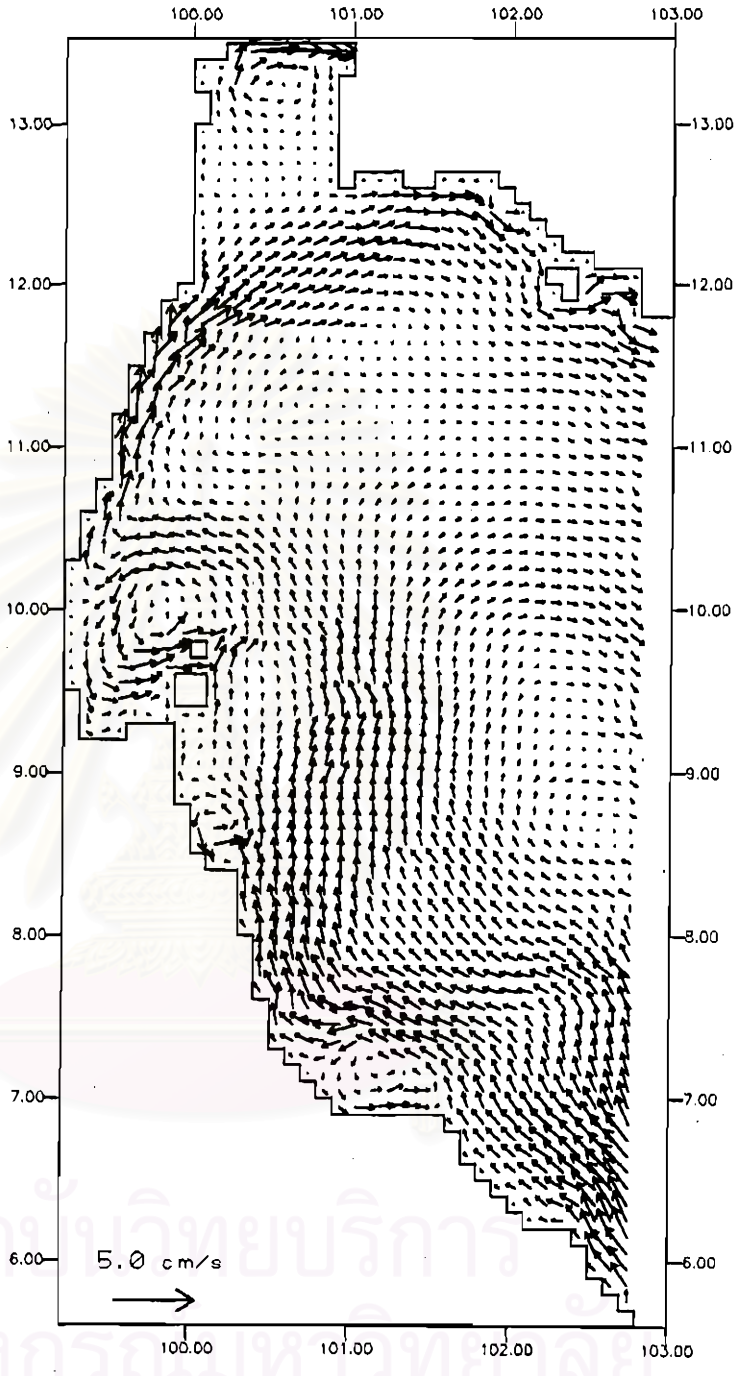


Figure 74. Monthly mean current in June, 1997.

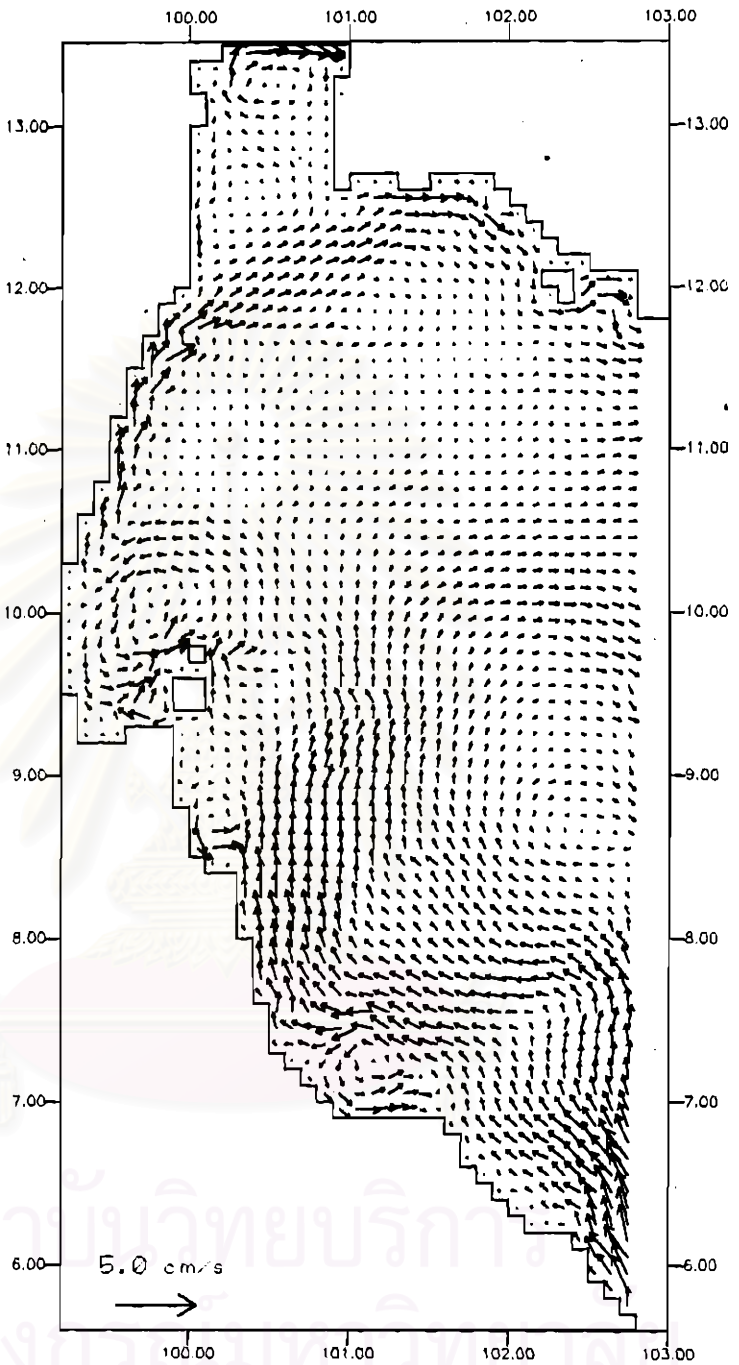


Figure 75. Monthly mean current in July, 1997.

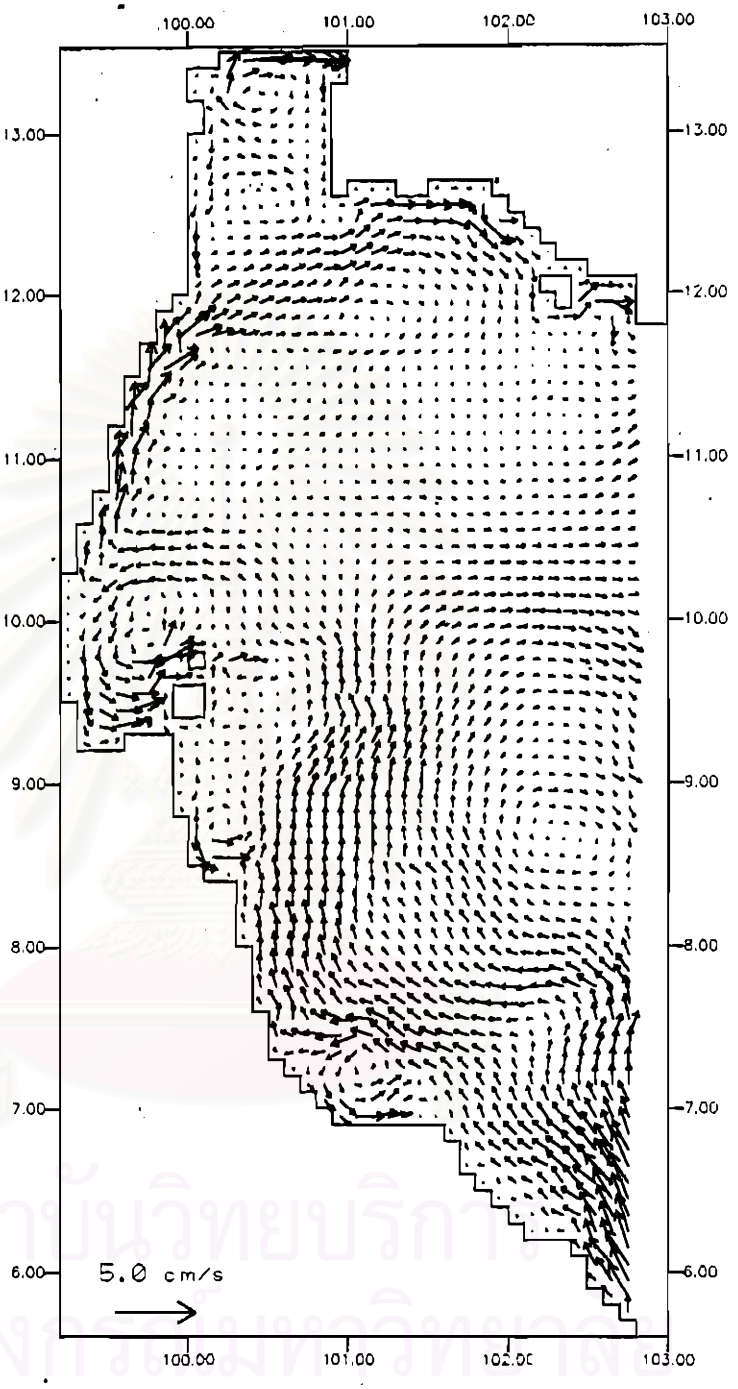


Figure 76. Monthly mean current in August, 1997.

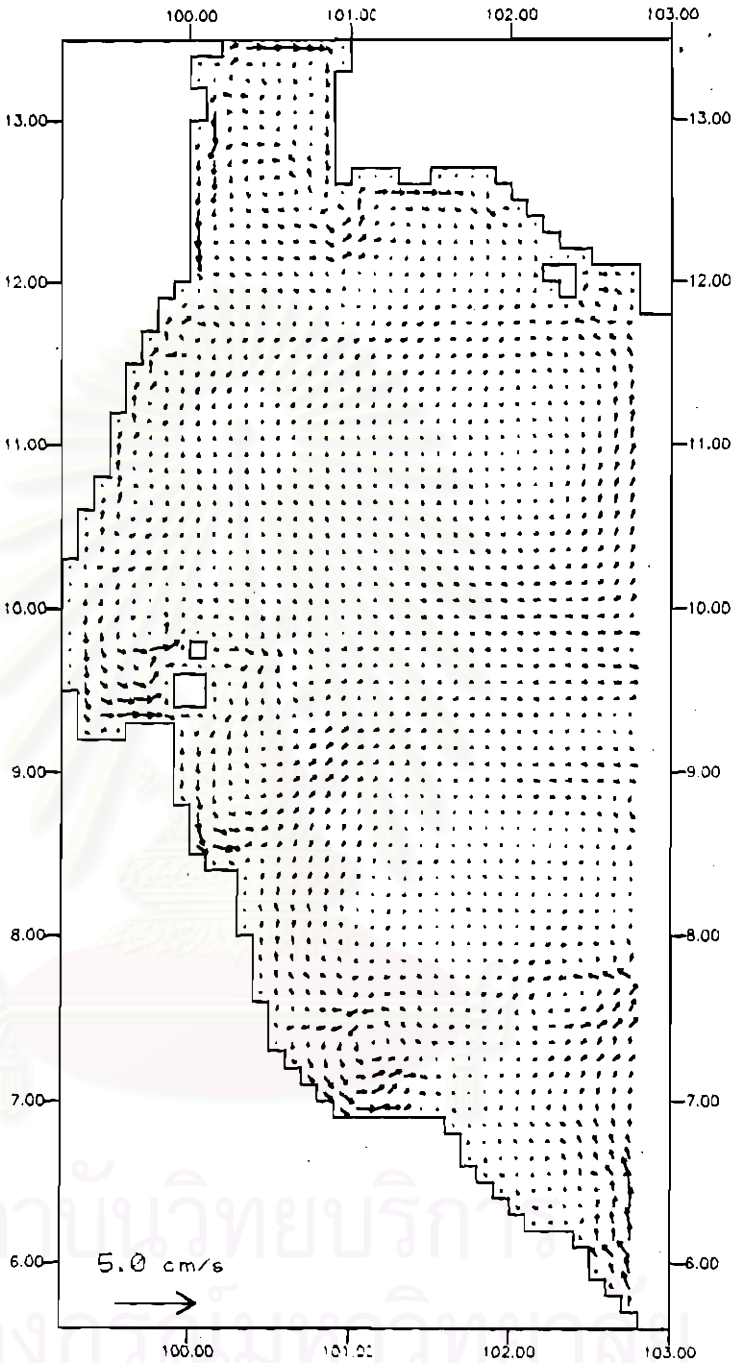


Figure 77. Monthly mean current in September, 1997.

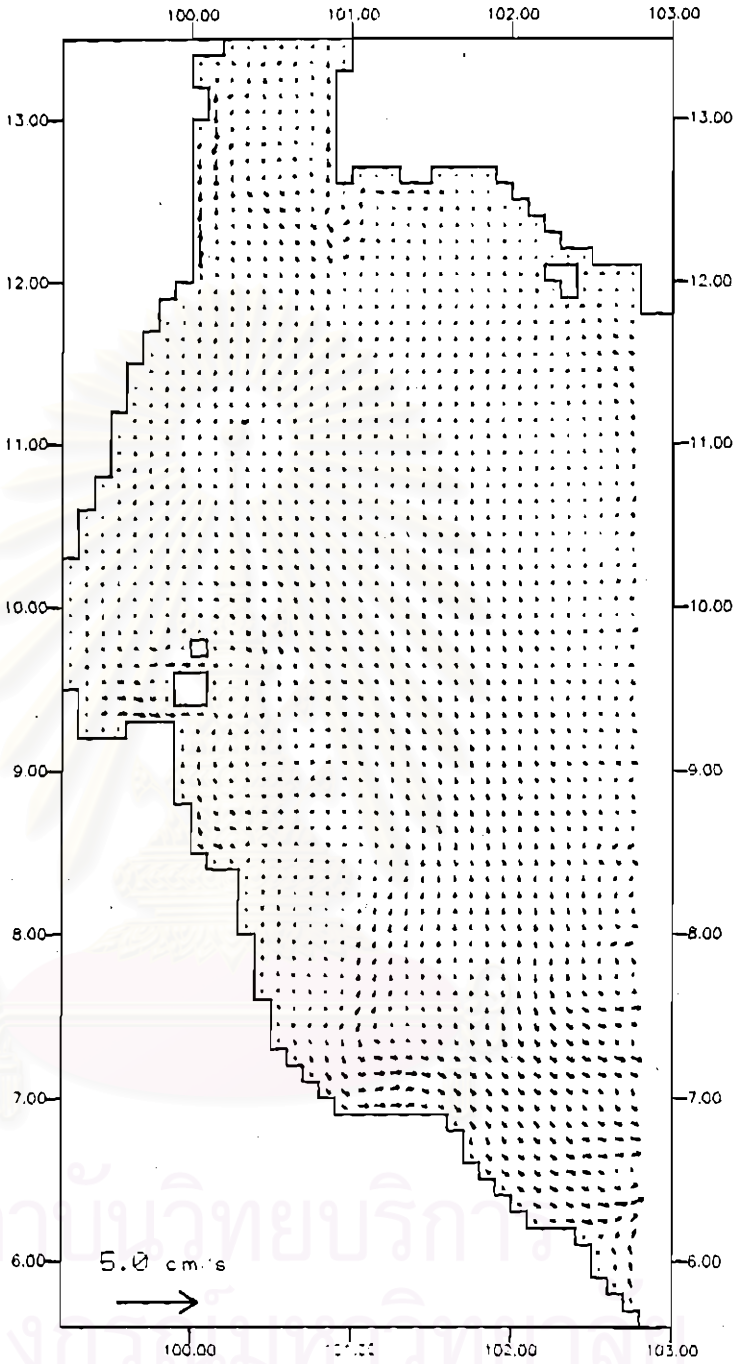


Figure 78. Monthly mean current in October, 1997.

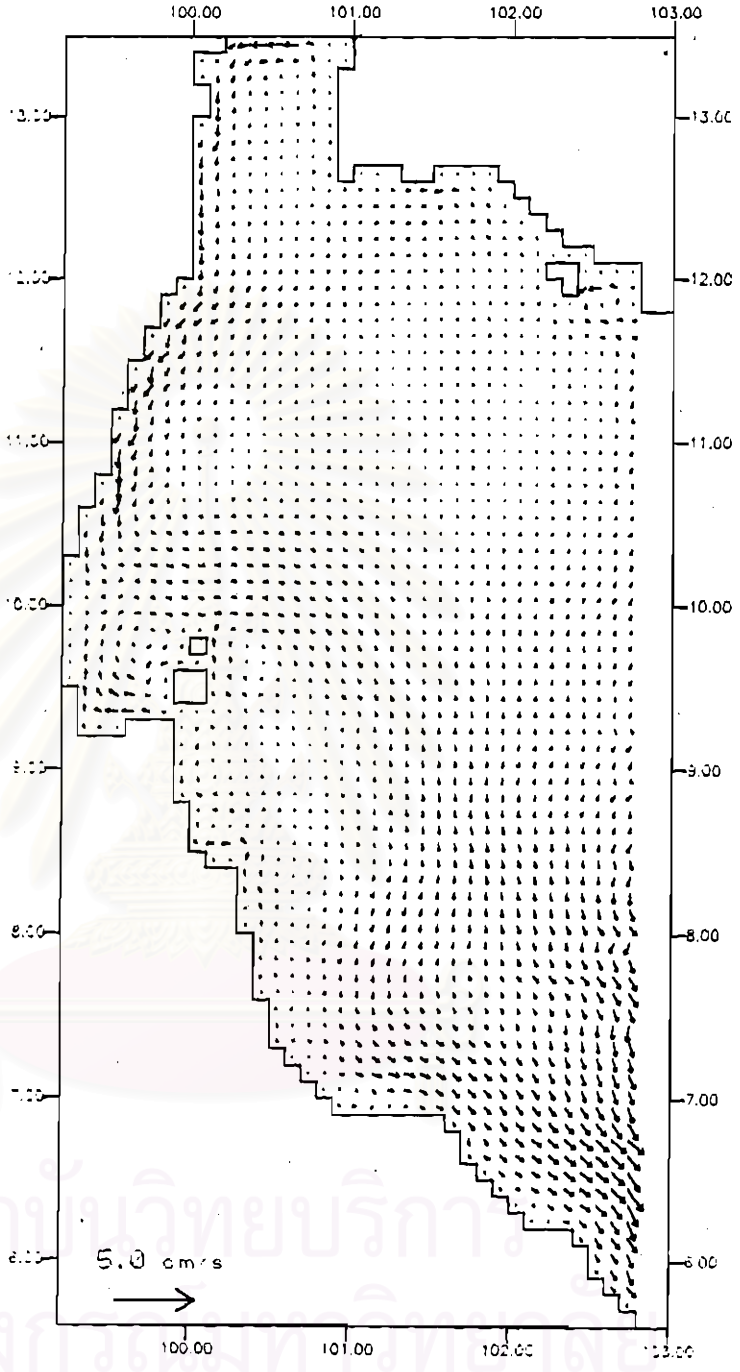


Figure 79. Monthly mean current in November, 1997.

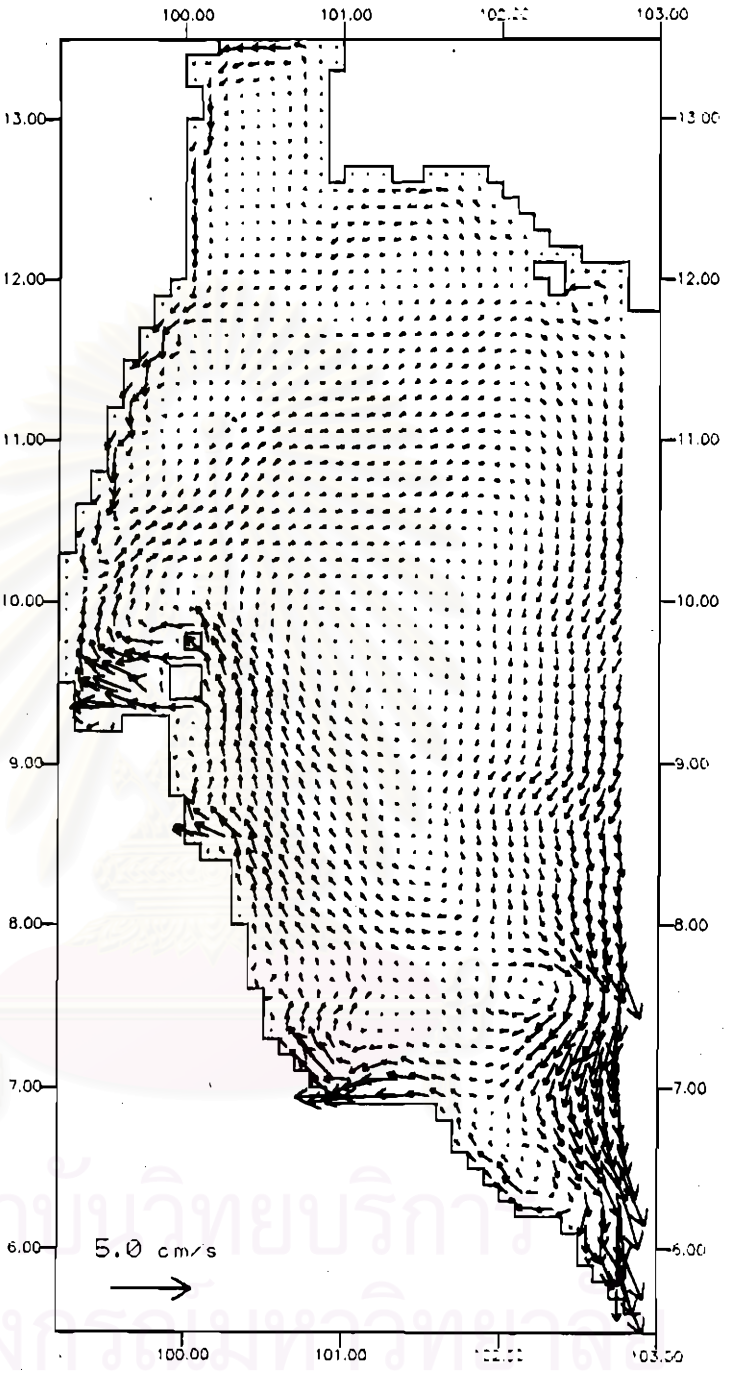


Figure 80. Monthly mean current in December, 1997.