Prediction of Aftershocks Distribution Using Self-Organizing Feature Maps (SOFM) and Its Application on the Birjand-Ghaen and Izmit Earthquakes

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ABSTRACT: *Self-Organizing Feature Maps (SOFM) have become powerful intelligent tools in recent years, used widely in pattern recognition and data clustering [5]. This paper has shown that SOFM can be used to predict the concentration and the trend of aftershocks of 1997 Birjand-Ghaen, Iran and 1999 Izmit, Turkey earthquakes. The present experiments using SOFM confirmed the algorithm could be applied for the prediction of local distribution of aftershock region.*

Keywords: Self-Organizing Feature Maps; Aftershocks; Prediction; Clustering; Concentration

1. Introduction

Aftershocks are most common immediately after the main shocks. Their average number of occurrences decreases rapidly as time passes, which depends on the geological conditions and the magnitude. The number of aftershocks per day is usually given by the modified Omori formula [8]. Omori [9] studied aftershocks in Japan and developed an empirical formula for the aftershock activity.

The principal properties of the aftershock sequences are described empirically as [8, 13]

$$R(t) = \frac{k}{(t+c)^p} \quad (1)$$

where $R(t)$ is the rate the occurrence of aftershocks and k, c, and p are constants. Of these three parameters, p is the most important. It measures the exponential decay rate of aftershocks. A larger p represents a faster decay. The aftershock distribution shows the rupture of the main shock, which is an important issue for estimating the risk of future disastrous earthquakes.

In general, the larger the main shock, the longer its aftershocks will be felt. Aftershocks tend to occur near the main shock, but the exact geographic pattern of the aftershocks varies from earthquake to earthquake. Statistically, aftershocks are not mutually independent in space. In the weeks and months after a strong earthquake, there will be many aftershocks, some strong enough to cause additional damage to structures already weakened due to the main shock.

In the present paper by application of Kohonen's unsupervised Self-Organizing Feature Maps, the possible prediction of the location of aftershock distribution will be described. The *SOFM* algorithms has been tested on the May 10, 1997 Birjand-Ghaen earthquake, and its stability is also examed on aftershocks August 17, 1999 Izmit earthquake.

2. Self-Organizing Feature Mapping Algorithm

2.1. Principle of the Learning Algorithm

The theory of Self-Organizing Feature Maps is fairly well understood and demonstrated [1, 2] and a number of applications of feature maps have also been developed. In the neural network community, the term Self-Organization refers to the ability of some networks to learn without being given the correct answer for an input pattern. Since there is no desired output given during the learning, the Self-Organizing Feature Mapping (*SOFM*) algorithm [6] is an unsupervised-learning process. The *SOFM* defines a mapping from the input data space on to an output layer by the processing units of e.g. 2-*D* laminar network become sensitive to the specific items of the input space in a topological order of the input items. Kohonen's algorithm creates a vector quantizer by adjusting weights from common input nodes to *M* output nodes arranged in a two dimensional grid as shown in Figure (1).

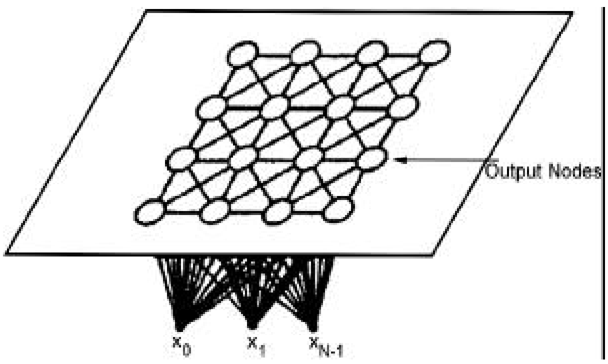


Figure 1. Two-dimensional array of output nodes used to form feature maps.

Output nodes are extensively interconnected with many local connections. Weights between input and output nodes are initially set to small random values and an input is presented. The distance between the input and all nodes is computed using

$$d_j = \sum_{j=0}^{N=1} (x_j(t) - w_{ij}(t))^2 \tag{2}$$

where d is distance between the input and each output node j at time t and w_{ij} is the weight from input node i to output node j at time t. If output node be substituted with minimum distance, then the new updated weighing becomes

$$w_{ij}(t+1) = w_{ij}(t) + \eta(t)(x_i(t) - w_{ij}(t)) \tag{3}$$

where $\eta(t)$ is a gain term value $0 \le \eta \le 1$ that decreases with time.

The Kohonen layer neurodes, on the other hand, receives not only the entire input pattern into the network, but also numerous inputs from the other neurodes within the layer. Building the Kohonen layer, two steps should be considered. First, to make sure that the weight vectors of the neurodes in the layer are properly initialized. Generally, this means that the weight vectors point in random directions around the unit circle. Second, the weight vectors and input vectors should be normalized before its use to a constant, fixed length usually one. These two steps are vital to the success of the Kohonen network. Only two-dimensional inputs with the weight vectors to unit length have been used. Each neurode in the Kohonen layer receives the input pattern and computes the scaler product of its weight vector with that input vector, in other words, the relative distance between its weight vector and the input vector. Each neurode has computed how close its weight vector is to the input vector. The neurodes then compete for the privilege of learning. In essence, the neurode with the largest scaler product is declared the winner in the competition. This neurode is the only neurode that will generate an output signal; all others generate 0. This is a completely new approach to learning before all of the neurodes in the network adjusted their weights on each training iteration. In general, these neurodes are those physically closest to the winning neurode. In a grid like array of neurodes, this neighborhood might comprise the neurodes that are one row or one column away from the winner.

During training, after enough input vectors, weights will specify cluster or vector centers that sample the input space [4]. Therefore the point density function of the vector centers tends to approximate probability density function of the input vectors. An optimal mapping would be the one that matches the probability density function best; i.e., to preserve at least the local structures of the probability function.

In contrast to the most of the other neural models, the "Self-Organizing Map" is concerned with the interaction between "microscopic" local adaptations and the "macroscopic" spatial structure or "topology" of the network. For practical applications, this provides an effective means to match the adaptation behavior of the network for a different region [3, 7].

2.2. Study of the Training Phase

For training the neural network, all of the input vectors are presented, one at a time, to the network. Each input vector is compared to every weight vector associated with every neuron, i.e. the Euclidean distance is computed. The one feature map neuron having the weight vector with the smallest difference to the current input is the winning neuron. The weight of this winning neuron is now updated in the direction of the input vector. This means, if this input vector is presented to the network for a second time, this neuron is very likely to be the winner again, and thus represent the class (or cluster) for this particular input vector. Clearly, similar input vectors will be associated with the winning neurons that are close together on the map.

The Kohonen network, models the probability distribution function of the input vectors used during training, with many weight vectors clustering in portions of the hypersphere that have relatively many inputs, and few weight vectors in portions of the hypersphere that have relatively few inputs. The Kohonen networks perform this statistical modeling, even in the cases where no closed-form analytic expression can describe the distribution. The Kohonen network can achieve this modeling spontaneously, with no outside tutor. The basic *SOFM* learning algorithm is to:

1. Choose initial values randomly for all reference vectors.
2. Repeat steps (3), (4), and (5) for discrete time.
3. Perform steps (4) and (5) for each input feature vector.
4. Find the best matching node according to (1).
5. Adjust the feature vectors of all the nodes for each node of the output layer according to

$$w_{ij}(t+1) = w_{ij}(t) + \eta(t)\left(x_i(t) - w_{ij}(t)\right). \tag{4}$$

Repeat this procedure until convergence, e.g. until the error between the input data and the corresponding neuron representing their class falls below a certain threshold. The vector position maps have been used (latitude and longitude) and arranged as a neat assembly of rows and columns, see Figures (2-1a) to (2-1e). In the simulation, 9 rows and 9 columns were used. Then the weight vectors were randomized and a special plot of their positions has been drawn. This plot will have a scaler corresponding to each neurode's weight vector, and a line will be drawn linking the scalers of neurodes that are neighbors in the matrix (only one row or one column away). When we begin to weight, vectors literally organize themselves so this plot maps the distribution function of the input pattern data. Figures (2-2a) to (2-2e) show the vector position map after the end of the training phase for prediction of concentration. The *SOFM* has very interesting properties for time series modeling. If the input pattern is allowed to be in any unusual pattern or distribution, the Kohonen network will always generate a map of that distribution. These plots look a little like a topological map of a hilly region. Where many input vectors are clustered, the grid is similarly bunched and crowded. Where only a few input vectors are clustered, the grid is much sparser. In this work, input sample space is latitude and longitude and the discrete output space respectively are 9*9 neurons that receive input from the previous layer and generate output to the next layer or outside world. When the network converges to its final stable state following a successful learning process, it displays three major properties:

1. The *SOFM* map is a good approximation to the input sample space. This property is important since it provide a concentration of representation of the given input space.
2. The feature map naturally forms a topologically ordered output space such that the spatial location of a neuron in the lattice corresponds to a particular domain in input space.
3. The feature map embodies a statistical law. In other words, the input with more frequent occurrence occupies a larger output domain of the output space. This property helps to make the *SOFM* an optimum codebook of the given input space.

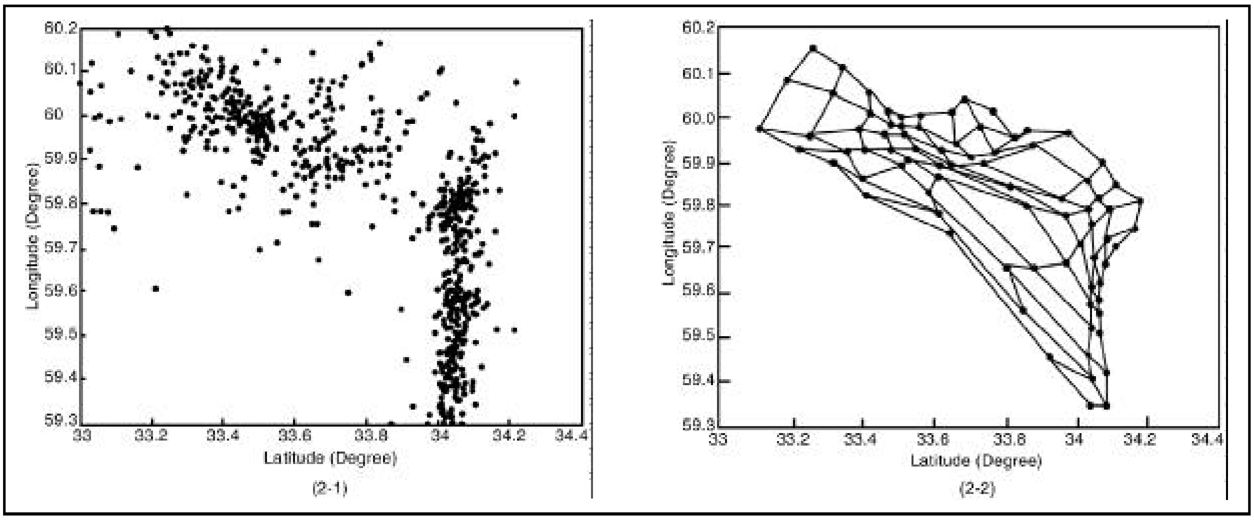
The straightforward way to take advantage of the above properties for prediction is to create a *SOFM* from the input vector, since such a feature map provides a faithful topologically organized output of the input vectors.

3. Prediction of Aftershock Distribution Using SOFM

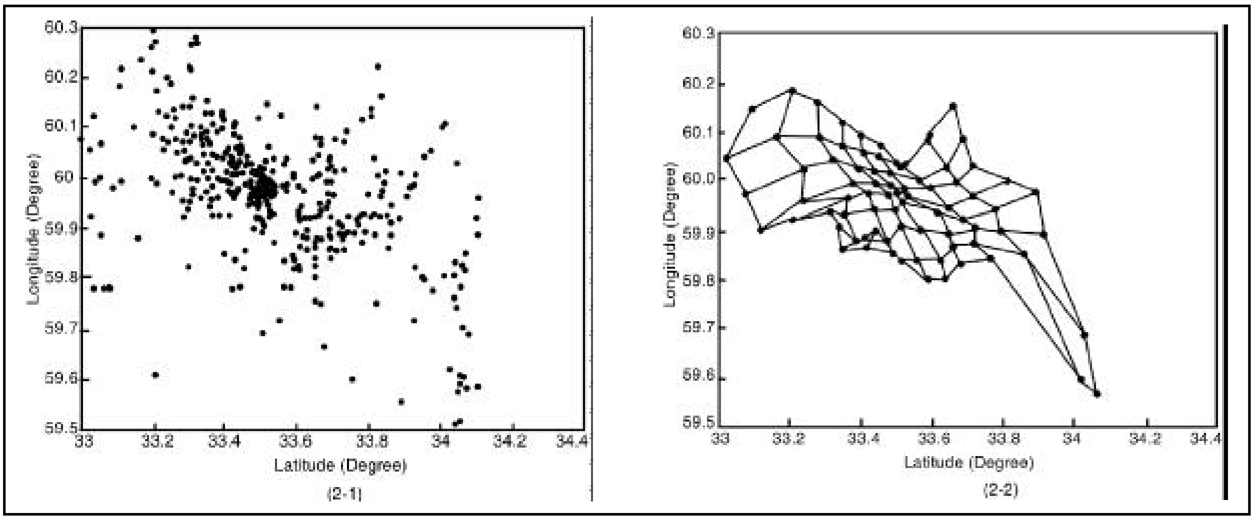
In this section, the *SOFM* will be tested on two recent earthquakes.

3.1. The 1997 Birjand-Ghaen Earthquake

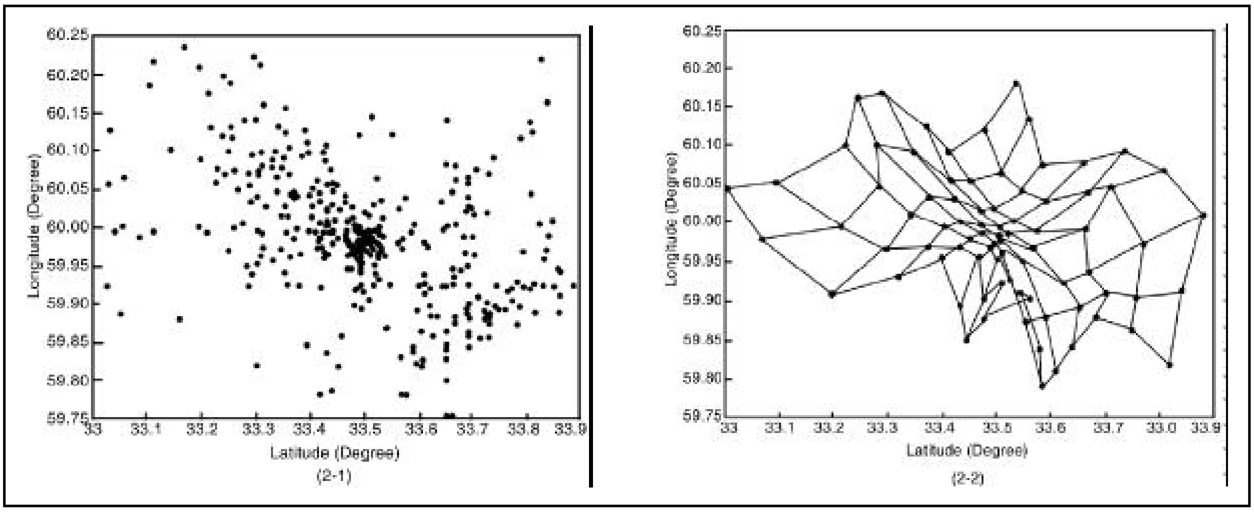
On 10 May 1997, a large earthquake (33.7*N*, 59.7*E*, *h*=27*km*, *Ms*=7.1) occurred in the northeastern part of Iran. The epicenter of the Birjand-Ghaen earthquake is situated in the north of the Sistan collision zone, which separates the central Iranian block on the west from the Afghanistan block on the east. The rupture zone extends 110*km*; striking *NNW-SSE*, with a dominant strike slip and a minor reverse slip component. In this part, the *SOFM* is tested for prediction of concentration of these aftershocks. In order to monitor the aftershock occurrence and the faulting mechanism, International Institute of Earthquake Engineering and Seismology (*IIEES*) had deployed a temporary seismic network of 5 stations in this area for a period of six weeks.



(a)

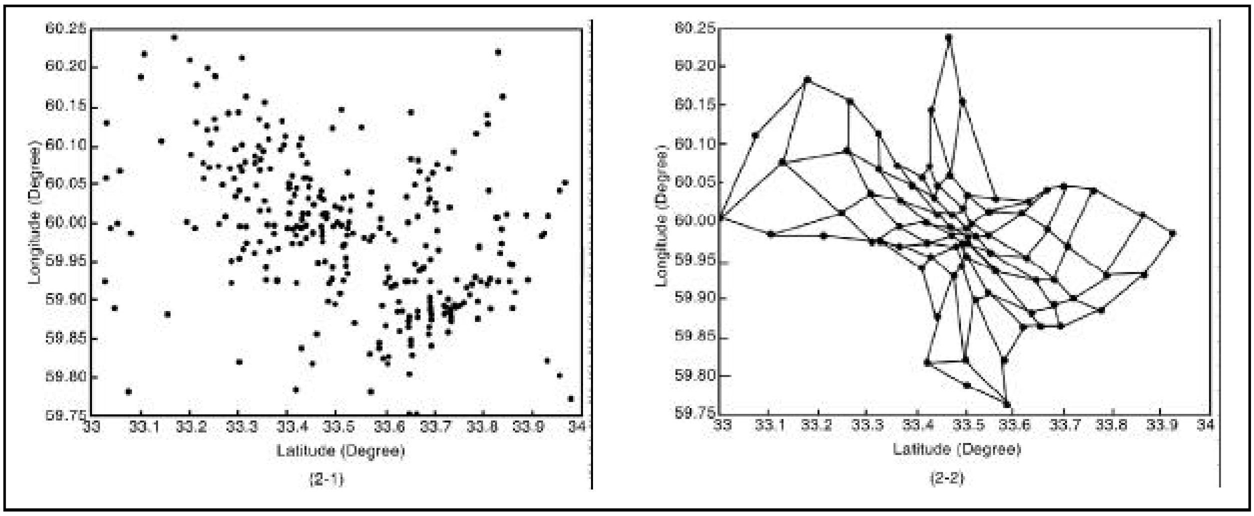


(b)



(c)

Figure 2. Summary of the actual event (Left) and simulation by self-organizing maps (Right) for the 1997, Birjand-Ghaen earthquake.



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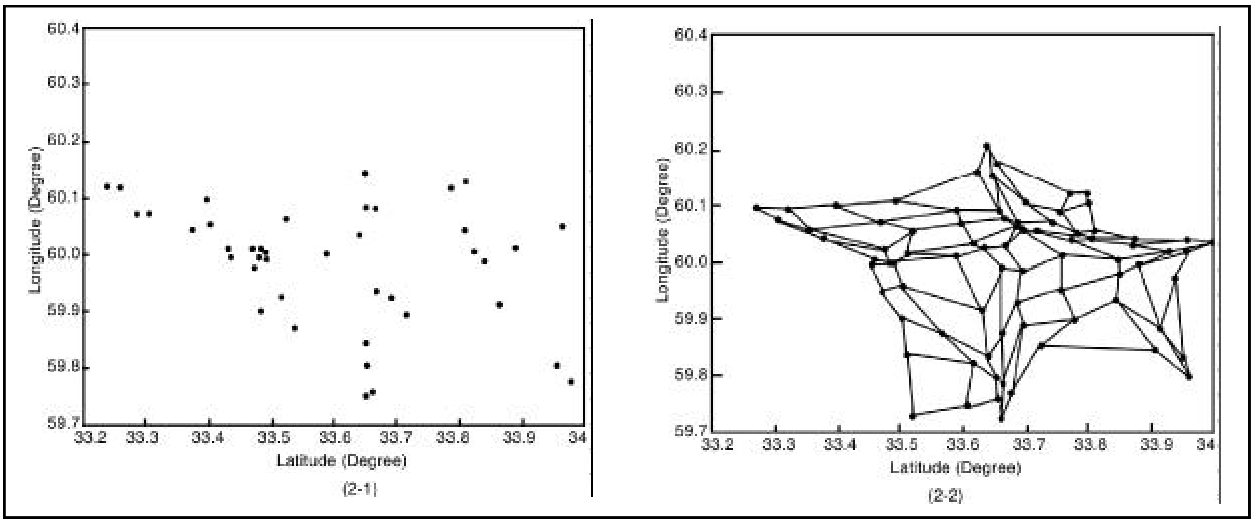


(e)

Figure 2. Continued ...

Figure (2-1a) shows the epicenter map of aftershocks ($Ml \geq 2.5$) recorded during this period [14]. We found a clear tendency that aftershocks occur in clusters, which implies strong heterogeneity in both the rupture process and the medium along the fault zone.

The input vector are latitude and longitude of events recorded at *IIEES* stations.

For the first test of the performance of the *SOFM,* a small subset of these data were applied. Figure (2-1e) shows the latitude and longitude of first input data. Figure (2-2e), *SOFM* provides a topologically organized output of the input vectors and predicted four clusters of aftershocks or distribution of earthquake swarms. One of these clusters near 33.5*N*, 50*E* predicted the center of concentration of aftershocks which is correct Identification and three clusters are Mis-Identification.

For the second and third test of the performance, a larger subset of these data were applied. Figures (2-1c) and (2-1d) show the input vectors (latitude, longitude) of first input data. As shown in Figures (2-2c) and (2-2d), *SOFM* predicted the center of concentration of aftershocks at 33.5*N*, 60*E*, without Mis-Identification.

For the fourth test of the performance, a larger subset than previous data sets were applied. As shown in Figure (2-2b), in addition to prediction of the concentration, the proposed approach can be used for identifying the activation region growing which will occur in future shown in Figure (2-1a). The results will be shown in Figure (2-1a) and Table (1).

Table 1. Performance of the clustering by SOFM.

Sample	Correct Prediction of Concentration	Mis-Identification
First (Small)	1	3
Second (Large)	1	0
Third (Larger)	1	0
Fourth (Larger than Previous)	Predict Activation of Region Growing	0

The input data in this analysis belong to some days of recording, see Figures (2-1a) to (2-1e).

The results of application of *SOFM* indicate that the proposed approach can be used for clustering of aftershocks and activation region growing [15], (Figures (2-2a) and (2-2b)), boundary detection area and obtaining an initial segmentation. The growing cell structure is another derivative of *SOFM* for prediction of the trend of aftershocks.

Figures (2-2a) to (2-2e) resemble a topographic map of input patterns and form highly-activated regions in response to input pattern. In the figures, the neurons moved closer to each other and predicted the center of concentration of aftershocks or earthquake swarms. *SOFM* reflects statistical variation in the aftershocks region, patterns with a high probability of occurrence are mapped on to a shrinked area and higher patterns have better resolution than patterns that have low probability of occurrence. There is a close resemblance between the actual and predicted events. The concentration of these events, both on recorded and predicted events are shown in the above-mentioned figures. The procedure of the application of this methodology is discussed.

For example, Table (2) shows the input vectors (latitude and longitude) for Kohonen's Self-Organizing networks and Appendix (*II*) shows the aftershocks data used in this study.

Table 2. Input data (Birjand-Ghaen).

Time	Latitude	Longitude	Magnitude
16:26:57.3	33.1100N	59.9940E	4.2
06:11:57.4	33.8940N	59.5601E	4.1
11:42:21.5	33.4430N	59.7886E	4.3
18:02:50.4	33.5786N	59.7836E	3.3
14:14:16.9	33.3943N	59.8476E	4.5
12:48:22.8	33.0380N	59.7836E	4.3
17:19:17.6	33.2030N	60.2683E	3.1
18:08:49.7	33.2995N	60.2200E	3.1
18:59:05.5	33.5000N	59.9166E	2.8
21:07:37.1	33.4950N	59.9183E	2.7
21:11:00.3	33.2000N	60.2950E	3.1

After several hundreds of iterations, the map of 9*9 output neurons has organized itself. The goal of training a self-organizing map is to separate the input data into several distinct clusters, which can be – in the 2*D* case- visualized on the 2-dimensional map. Neurons in a 2-*D* layer learn to represent different regions of the input space where input vectors occur. In addition, neighboring neurons learn to respond to similar inputs, thus the layer learns the topology of the presented input space.

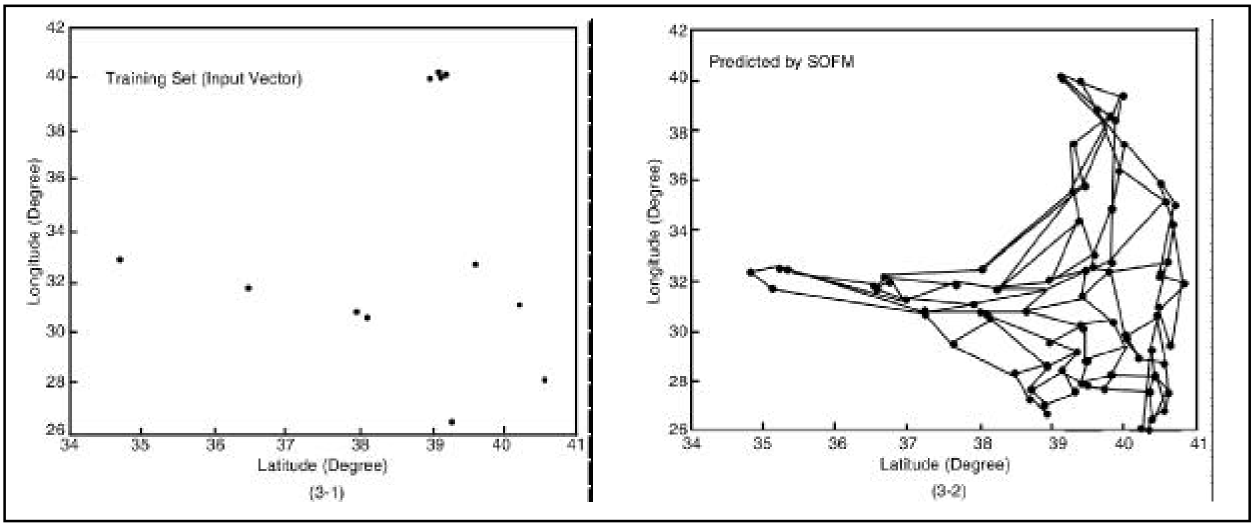
After enough input vectors have been presented, in Figures (2-2a) to (2-2e) weights will specify cluster or vector centers that sample the input space such as the probability density function of the input vectors. In addition, the weights will be organized such that topologically close nodes are sensitive to inputs that are physically similar. As an example based on the above discussion, Figures (2-1a) to (2-1d) show the concentration and clustering of aftershocks, wrinkled by neurons of the weight vectors on the map. Figure (2-2a) to (2-2d) present the values of the synaptic weight vectors, plotted as dots in the input space, after 800 iterations. The total number of weights in the neural network is 81. The performance index of learning rate (*lr*) was 0.094 with 800/2000 epochs.

3.2. The Aftershock Region of the 1999 Izmit Earthquake

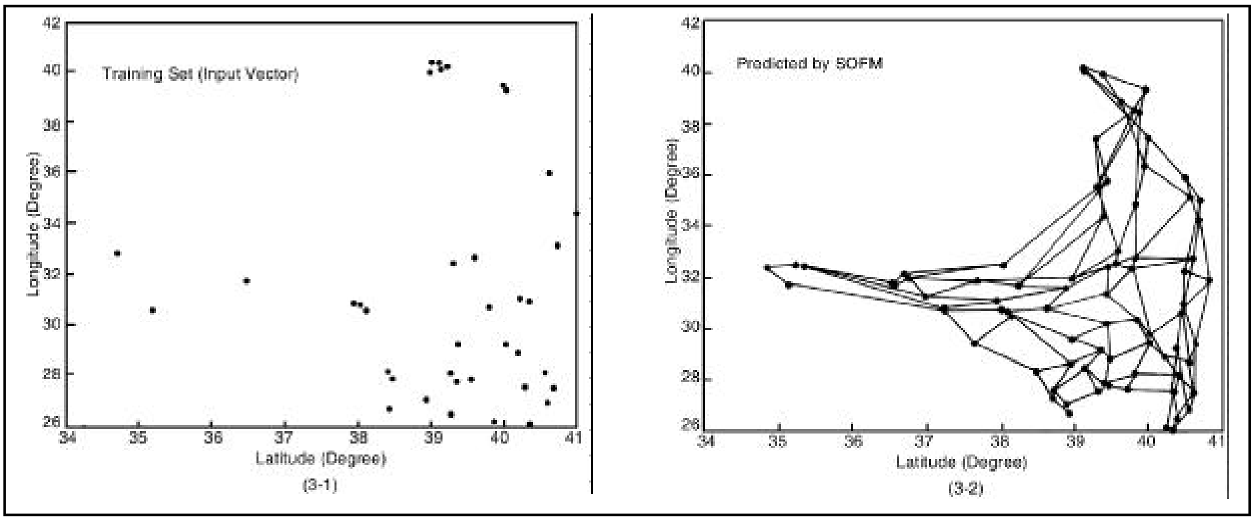
The final example in Figure (3) shows the summary of actual events (aftershocks of the 1999 Izmit earthquake [10, 11, 12]) in left side of each diagram and simulation estimated by self-organizing feature maps in right side of each diagram.

Five recognition experiments were performed and compared together. In first experiments, each one of data sets were recognized by the nearest neighbor neurons. We had five such cases and obtained similar experiments using these data sets.

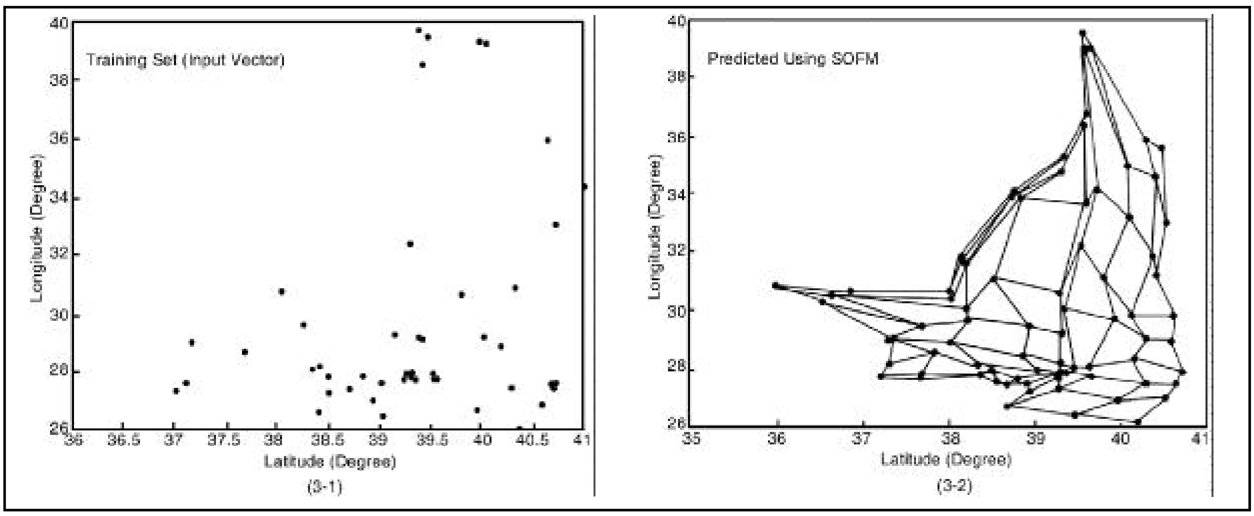
When these 2-dimensional input vectors (latitude



(a)

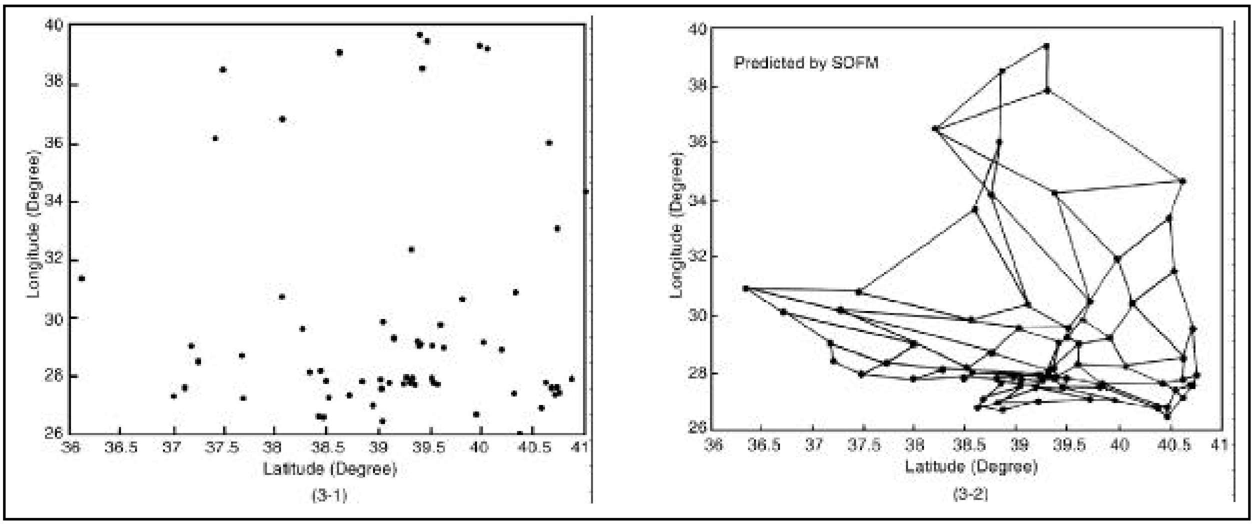


(b)

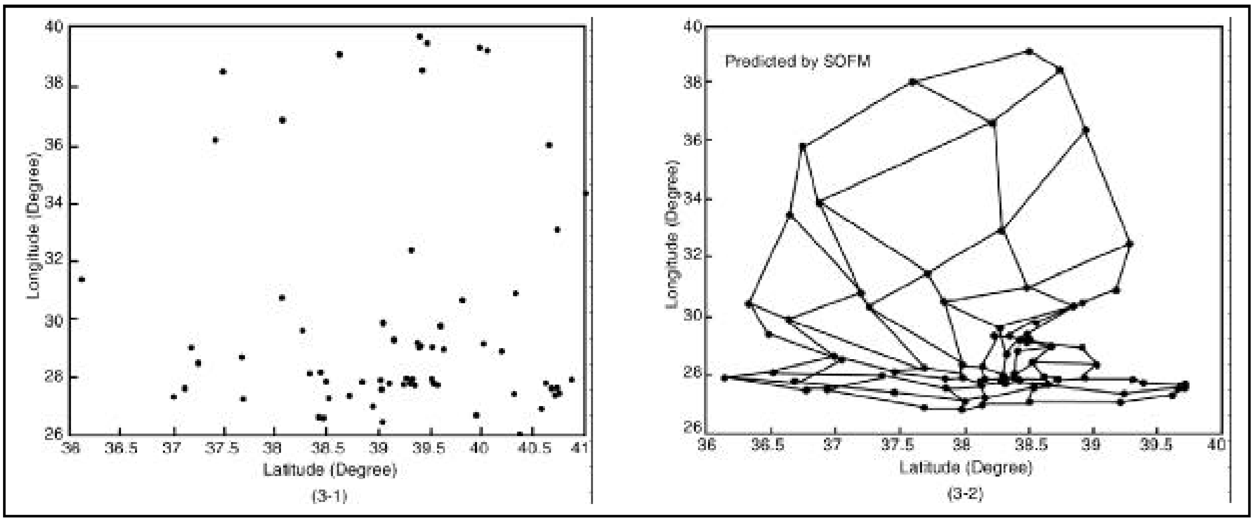


(c)

Figure 3. Summary of the actual event (Left) and simulation estimates by self-organizing feature maps (Right) for the 1999, Izmit earthquake.



(d)



(e)

Figure 3. Continued ...

and longitude) are presented to the system, it organizes itself and the mapping directly resembles the abstract case which shows the prediction of concentration of aftershocks. In this analysis, clustering can be viewed as a mapping by neurons. The neurons specify clusters that sample the input space such that the point density function of the centers of clusters tend to approximate the probability density function of input patterns.

The data of the Izmit earthquake ($Mw = 7.2$) 1999, were recorded by *IZINET* (Izmit Network) permanent network and 10 temporary seismic stations were installed for the period of about 2 months [12]. More than 2000 aftershocks were recorded during this period. In this study, the aftershocks data occurred between 17 August and 10 October 1999 were used with magnitude greater than or equal to 2.5, see Appendix (*I*). Figure (3-1e) shows the analysis of the actual recorded hypocentral distributions in this region. For the first and second test of the performance of the *SOFM,* a small subset of these data were applied. Figures (3-1a) and (3-1b) show the location (latitude, longitude) of first input data.

As shown in Figures (3-2a) and (3-2b), *SOFM* provide a topologically organized output of input vectors and predicted five clusters of aftershocks. Two of these clusters 39.5*N*, 28*W* and 40.5*N*, 28*W* predicted correct Identification (compared with Figure (3-1e) and three clusters are Mis-Identification.

For the third and Fourth test of the performance, a larger subset than previous data sets were applied. In Figures (3-2c) and (3-2d), the predicted location by *SOFM* are shown, see also Figure (3-1e).

The results are shown in Table (3). Figures (3-1a) to (3-1e) show the concentration and clustering of

Table 3. Performance of the Clustering by SOFM.

Sample	Correct Prediction of Concentration	Mis-Identification
First (Small Set)	2	3
Second (Large Set)	2	3
Third (Larger than Previous)	2	1
Fourth (Larger than Previous)	2	0

Izmit aftershocks. The values of the synaptic weight vectors which wrinkled by neurons on the maps are shown in Figures (3-2a) to (3-2e).

It is found that a large number of aftershocks occurred as clusters are predicted using the present nonlinear system. As can be seen in Figures (3-2c) and (3-2d), the *SOFM* has shown satisfactory result for prediction of the clusters of aftershock in this local region, see also Figure (3-1e).

In this experiment, algorithm showed that there is a close resemblance between the actual Figure (3-1e) and predicted events in Figures (3-2a) to (3-2e). According to Kohonen, the exact form of the neighborhood is not important. A rectangular neighborhood is supported for ease of implementation. The width and height of the neighborhood are configurable via two parameters. These parameters are decremented at the end of *N* epochs to create a shrinking neighborhood during learning (Number of Neuron =8*8 Train *SOFM*: 810/2000 epochs with *lr* = 0.00952786). Our experiments demonstrated the basic effectiveness and adaptability of the *SOFM* for prediction of aftershocks distribution. Several significant features in the distribution of the aftershocks can be recognized. Aftershocks occurred mainly in four regions during this period and did not occur along the surface rupture, which is predicted by *SOFM*.

4. Conclusions

Aftershock forecasts assist government, industry, and emergency response teams in deciding when it is safe to demolish, repair, or allow people to use damaged structures. In taking this approach one step further, seismologists are now trying to compute actual probabilistic aftershock hazard maps.

In general, the presented results supports the Kohonen's Self-Organizing Feature Maps (*SOFM*) methodology for predicting the concentration of aftershocks. This method could also be used to predict concentration of aftershock zone and the trend of aftershocks in future. An additional application of the method could also be used in defining the overlapping (imprecise boundaries) where there is no clear boundary between the aftershock of two different main events. This discussion of Kohonen learning needs to address the problem of normalization of the weights and input vectors. If the network is needed to predict the clusters, the normalization procedures need to be followed. Proper initialization of the weight vectors is another problem in applying Kohonen networks. Kohonen networks work best when the input vector distribution is closed, therefore, this program functions best for local region.

There are number of advantages to the presented *SOFM* method. First, *SOFM* reflects statistical variation in the aftershocks region; patterns with a high probability of occurrence are mapped on to a larger area of the *SOFM*. Higher density patterns have better resolution than patterns that have low probability of occurrence.

As shown in Figures (2-2a) and (2-2b), *SOFM* stored a large set of input vectors (location of aftershocks) by finding a small set of prototypes (approximations of the region growing) and units with similar features are placed in proximity on the shrinked networks. It is possible for these networks to literally learn continuously. Thus if the statistical distribution of the input data changes over time, the Kohonen network can automatically adapt to those changes and continually model the current distribution of the input pattern data. The fact that the Kohonen networks will self-organize into the correct statistical model make them without peer for some applications in seismology. In the future, we can determine a station correction for the inaccuracies of the model structure along the travel path and beneath the station by using this algorithm.

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Appendix I. *Aftershocks data of 17 August 1999 of Izmit earthquake in Turkey used in this study.*

Date (DD. MM.YY)	Local Time (Hour, Min., Sec.)	Lat. (N)	Long. (W)	Dep. (Km)	Mag. (MD)
17/08/99	18:06:26.6	34.70	32.87	37.0	5.0
17/08/99	18:06:26.7	34.71	32.87	37.0	5.0
18/08/99	18:50:12.0	40.23	31.08	31.9	4.0
21/08/99	21:41:55.8	39.00	39.99	18.7	3.9
22/08/99	14:12:56.4	39.14	40.10	10.6	4.3
22/08/99	15:18:11.4	39.11	40.24	14.1	3.9
22/08/99	20:40:01.2	39.29	26.49	1.0	3.5
23/08/99	22:46:32.0	39.22	40.13	1.0	3.7
23/08/99	23:01:58.3	40.57	28.10	14.7	3.4
24/08/99	10:41:02.4	39.85	26.16	8.9	3.2
24/08/99	20:33:15.1	39.61	32.62	8.7	4.7
25/08/99	20:46:10.8	36.48	31.76	31.0	3.8
26/08/99	08:37:57.5	37.97	30.80	5.4	4.0
26/08/99	09:35:57.2	38.12	30.58	9.3	3.8
27/08/99	11:44:55.8	40.33	30.94	12.9	3.3
28/08/99	16:50:50.4	39.99	39.39	13.7	3.5
28/08/99	23:16:29.5	35.20	30.62	31.4	4.5
29/08/99	0:03:02.2	39.37	29.22	10.0	3.2
29/08/99	04:15:14.5	40.19	28.92	10.0	3.1
30/08/99	02:24:14.9	39.53	27.78	13.9	3.5
30/08/99	09:51:15.7	39.31	32.40	2.1	4.1

Date (DD. MM.YY)	Local Time (Hour, Min., Sec.)	Lat. (N)	Long. (W)	Dep. (Km)	Mag. (MD)
31/08/99	09:50:14.0	41.08	29.09	19.4	2.9
31/08/99	10:38:59.5	40.58	26.92	3.3	3.3
31/08/99	23:36:32.3	40.69	27.47	1.0	3.0
01/09/99	03:59:46.8	40.04	39.31	5.6	3.3
01/09/99	14:56:48.0	41.00	34.38	5.0	3.2
02/09/99	11:11:34.8	39.56	27.77	16.5	3.3
03/09/99	10:04:43.4	40.02	29.22	12.1	3.0
03/09/99	13:00:06.7	38.42	26.66	11.5	3.6
04/09/99	06:40:54.8	39.40	29.18	16.0	3.3
04/09/99	22:55:53.9	38.94	27.04	5.5	3.6
05/09/99	00:47:19.4	38.05	30.76	1.0	3.8
05/09/99	09:57:09.7	38.49	27.86	81.5	2.9
05/09/99	11:32:01.1	39.04	40.28	5.4	3.6
07/09/99	12:59:23.5	40.30	27.48	8.8	3.0
08/09/99	12:45:46.5	40.63	36.01	3.9	3.4
08/09/99	15:20:46.1	40.73	33.14	5.0	3.7
09/09/99	11:12:02.7	40.36	26.08	33.4	4.5
09/09/99	11:15:35.4	40.39	25.66	18.4	4.9
09/09/99	16:04:46.6	38.42	28.16	5.4	3.0
09/09/99	22:26:48.7	39.27	27.98	12.3	3.1
10/09/99	09:00:10.3	39.36	27.73	1.1	3.1

Appendix I. Continued ...

Date (DD. MM.YY)	Local Time (Hour, Min., Sec.)	Lat. (N)	Long. (W)	Dep. (Km)	Mag. (MD)
10/09/99	16:24:26.7	39.81	30.73	13.4	3.0
10/09/99	18:26:52.1	39.32	27.89	9.0	3.6
10/09/99	20:08:04.1	37.02	27.39	1.0	3.5
11/09/99	02:57:25.1	39.52	27.92	9.3	3.5
11/09/99	15:39:8.0	37.68	28.74	5.0	2.9
13/09/99	16:18:35.4	39.29	27.86	9.4	3.0
13/09/99	18:59:02.0	39.16	29.32	6.8	3.0
13/09/99	21:07:01.4	38.35	28.15	6.9	3.1
13/09/99	07:19:44.2	37.12	27.63	1.0	3.0
14/09/99	12:55:05.2	39.47	39.53	1.0	3.7
14/09/99	21:55:35.6	38.70	27.44	5.0	3.0
15/09/99	09:12:53.4	39.33	27.89	5.1	3.0
15/09/99	12:07:22.2	38.26	29.67	1.0	3.2
16/09/99	08:03:41.1	39.24	27.74	7.7	3.1
16/09/99	08:39:33.8	39.24	27.78	10.5	3.5
16/09/99	11:20:11.2	39.32	27.96	5.6	3.4
16/09/99	12:25:20.7	39.03	26.53	1.0	3.7
16/09/99	16:10:15.3	39.29	27.90	5.5	3.1
17/09/99	0:51:27.4	39.43	38.57	9.7	3.6
17/09/99	12:19:14.2	39.95	26.74	1.0	3.3
19/09/99	18:50:36.5	38.84	27.86	26.9	3.5
19/09/99	19:11:53.2	37.18	29.07	5.0	3.5
19/09/99	21:36:33.4	39.02	27.64	5.0	3.1
19/09/99	22:39:01.2	38.51	27.32	5.0	3.1
20/09/99	08:01:10.7	36.12	31.36	26.8	3.6
20/09/99	19:07:44.2	39.31	27.87	12.4	3.7
20/09/99	21:44:34.0	39.40	39.77	9.9	3.6
20/09/99	23:36:39.0	40.70	27.57	7.0	3.5
21/09/99	00:28:00.0	40.69	27.58	16.4	5.0
21/09/99	00:44:31.8	40.70	27.59	7.8	3.7
21/09/99	01:16:40.6	40.71	27.59	5.9	3.2
21/09/99	02:40:08.1	40.72	27.60	7.2	3.4
21/09/99	04:09:15.8	40.71	27.56	15.8	3.5
21/09/99	07:34:33.2	40.70	27.57	6.3	2.8
21/09/99	08:33:50.7	39.32	27.80	10.4	3.0
21/09/99	09:10:07.9	39.35	27.85	26.7	3.2
21/09/99	112056.2	39.52	29.11	5.0	2.7
21/09/99	13:12:58.3	39.39	29.10	8.2	2.8
21/09/99	15:46:20.3	40.70	27.57	7.5	3.3
21/09/99	16:54:12.6	37.26	28.52	6.7	3.3
21/09/99	17:02:41.0	40.71	27.57	6.8	2.7
21/09/99	19:10:46.4	40.68	27.55	11.0	2.5
21/09/99	17:14:02.1	40.71	27.57	6.2	2.9
21/09/99	19:47:23.0	40.86	27.96	10.9	2.8
21/09/99	23:34:12.0	40.72	27.59	6.9	3.1
22/09/99	10:42:37.2	39.29	27.89	5.1	2.9
22/09/99	11:29:18.5	40.67	27.61	3.6	2.8
22/09/99	15:28:13.0	40.72	27.57	5.4	2.8
22/09/99	2:33:33.2	39.63	29.01	8.8	3.1
23/09/99	02:02:18.5	40.62	27.82	9.0	3.2
23/09/99	10:37:47.5	38.06	36.83	10.0	3.3
23/09/99	12:54:42.7	38.46	26.63	13.4	3.6
23/09/99	17:58:28.3	38.37	28.18	11.6	3.2
24/09/99	11:13:07.3	39.60	29.81	12.0	2.7
24/09/99	13:01:46.5	40.75	27.54	5.5	2.5
24/09/99	21:28:18.5	40.74	27.54	6.3	3.1
24/09/99	22:08:04.7	37.51	38.53	16.2	4.5
25/09/99	01:59:26.9	37.42	36.22	5.0	3.8
25/09/99	23:17:48.1	38.62	39.13	28.0	3.5
26/09/99	00:10:22.1	37.69	27.28	13.4	3.6
26/09/99	10:19:32.5	39.04	29.91	5.0	3.2
26/09/99	09:38:38.7	39.02	27.92	9.0	4.1
26/09/99	10:46:39.5	39.09	27.83	1.0	2.9
26/09/99	22:18:01.0	39.84	39.36	1.3	3.4
26/09/99	23:15:19.0	38.99	27.91	5.0	2.9
27/09/99	00:05:25.4	39.20	27.48	5.0	3.0
27/09/99	00:31:37.1	39.45	29.10	11.1	2.7
27/09/99	04:30:42.3	39.19	27.29	5.5	2.9
27/09/99	05:30:31.0	39.17	26.95	6.6	2.9
27/09/99	06:45:31.0	39.15	26.97	5.4	3.0
27/09/99	07:02:02.5	39.12	26.90	19.5	3.5
27/09/99	09:19:36.1	39.42	27.94	11.3	2.9
27/09/99	16:21:40.1	40.71	27.56	5.2	3.0
27/09/99	22:58:30.1	37.03	35.53	32.8	3.5
28/09/99	02:47:42.6	39.10	27.19	27.7	3.3
28/09/99	02:56:53.2	39.00	27.78	1.0	3.5
28/09/99	23:31:51.0	40.53	38.80	4.1	3.4
29/09/99	04:37:09.0	39.05	27.81	5.3	3.0
29/09/99	11:21:38.1	39.55	29.61	6.1	2.7
29/09/99	13:54:34.9	39.94	27.80	1.0	2.5
29/09/99	19:46:33.2	39.09	28.83	9.3	3.7
30/09/99	17:08:19.7	39.00	26.42	5.0	3.2
30/09/99	21:39:42.3	38.72	27.47	3.7	3.0
02/10/99	14:28:50.5	40.76	27.51	14.6	3.4
03/10/99	02:31:13.8	40.01	28.09	8.1	2.6
03/10/99	02:18:12.8	38.26	33.10	1.0	3.9
03/10/99	03:16:23.3	39.64	28.79	8.4	2.7
03/10/99	06:55:30.8	39.65	38.14	1.0	3.8
03/10/99	18:48:52.0	36.42	30.59	23.5	3.9
03/10/99	20:56:36.8	39.67	38.19	17.6	3.3
04/10/99	00:43:51.0	40.67	27.51	5.3	2.9
04/10/99	15:52:28.0	41.02	30.32	5.0	3.0
04/10/99	17:19:48.1	39.01	27.96	9.6	3.6
05/10/99	03:53:26.9	36.80	28.14	23.6	5.2
05/10/99	04:04:56.4	36.94	28.07	11.4	4.2
05/10/99	09:59:54.1	40.72	27.60	8.0	2.8
05/10/99	20:20:56.6	37.79	29.16	19.5	3.1
06/10/99	09:59:03.4	40.72	27.60	6.0	3.1
06/10/99	10:28:47.0	39.22	27.78	10.5	2.9
06/10/99	11:40:45.5	39.33	27.72	5.6	2.8
06/10/99	17:05:22.8	40.68	27.56	12.1	2.7
07/10/99	03:55:14.4	40.71	27.59	6.0	3.2
07/10/99	11:27:56.6	39.29	27.65	8.5	2.8
07/10/99	23:52:32.1	39.08	27.74	3.8	3.3
08/10/99	11:20:50.0	39.99	27.90	8.6	3.1
09/10/99	21:30:01.2	38.69	32.17	1.0	3.2
09/10/99	22:02:11.7	40.30	30.83	9.0	2.9
09/10/99	23:40:34.9	39.11	27.81	2.8	2.9
10/10/99	08:11:02.9	39.14	29.42	7.8	2.9
10/10/99	13:20:43.7	39.80	28.08	1.0	2.6
10/10/99	15:35:24.2	40.51	27.74	1.0	2.7

Appendix II. *Aftershocks data of 10 May, 1997 Birjand-Ghaen earthquake in Iran used in this study.*

Date	Time	Lat.	Long.	Dep.	Mag.
12/5/1997	26:57.3	33.1100N	59.9940E	10	4.2
13/5/1997	11:57.4	33.8940N	59.5601E	10	4.1
13/5/1997	42:21.5	33.4430N	59.7886E	10	4.3
13/5/1997	02:50.4	33.5786N	59.7836E	18.3	3.3
14/5/1997	14:16.9	33.3943N	59.8476E	10	4.5
15/5/1997	48:22.8	33.0380N	59.7836E	10	4.3
15/5/1997	19:17.6	33.2030N	60.2683E	14.4	3.1
15/5/1997	08:49.7	33.2995N	60.2200E	15.7	3.1
15/5/1997	59:05.5	33.5000N	59.9166E	15.1	2.8
15/5/1997	07:34.1	33.4950N	59.9183E	15.3	2.7
15/5/1997	11:00.3	33.2000N	60.2950E	2	3.1
15/5/1997	53:24.5	33.2493N	59.9698E	3	2.3
15/5/1997	03:25.9	33.5433N	59.9750E	17.2	2.1
15/5/1997	16:29.1	33.2912N	59.9422E	12.3	2
15/5/1997	39:16.0	33.0616N	59.7833E	6	3.3
15/5/1997	47:47.6	33.7125N	59.8570E	12.1	2.1
15/5/1997	52:01.2	33.2860N	59.9222E	6	2.2
15/5/1997	59:20.9	33.6916N	59.9250E	6	2.2
15/5/1997	13:42.0	33.3118N	59.9947E	15.8	2.3
16/5/1997	07:10.5	33.6516N	59.8650E	6	2.5
16/5/1997	11:01.0	33.5658N	59.8333E	5.4	2.1
16/5/1997	18:36.8	33.4283N	60.0316E	6	2.5
16/5/1997	54:05.9	33.6116N	59.9833E	4.5	2.6
16/5/1997	27:40.7	33.9083N	59.9633E	23.4	2.1
16/5/1997	50:42.4	33.3000N	60.1400E	22.7	3.3
16/5/1997	03:30.2	33.4333N	59.9650E	29.1	2.9
16/5/1997	23:23.3	33.2150N	60.1316E	25.2	2.4
16/5/1997	12:17.7	33.6066N	59.8283E	8.8	3.3
16/5/1997	27:31.5	33.5133N	59.9866E	16.5	3.5
16/5/1997	54:33.8	33.8300N	59.9256E	1.4	3.1
16/5/1997	12:26.7	33.4883N	59.9783E	10.3	3.5
16/5/1997	07:14.0	33.4433N	60.0100E	10	3.5
16/5/1997	52:49.6	33.4400N	60.0316E	0.8	3.6
16/5/1997	00:22.4	33.4250N	59.9633E	10.5	3.5
16/5/1997	27:19.9	33.4150N	59.9733E	10.9	3.6
16/5/1997	57:29.8	33.7933N	59.9250E	10.8	3.7
16/5/1997	38:38.4	33.3583N	59.9950E	0.2	3.6
16/5/1997	33:07.6	33.4816N	60.0100E	10.9	3.4
16/5/1997	59:55.0	33.1333N	60.4000E	29.5	3.8
16/5/1997	31:46.2	33.4918N	59.9250E	0.1	3.6
16/5/1997	06:51.1	33.9283N	59.8233E	13.8	3.5
16/5/1997	18:02.3	33.5683N	59.7833E	18.3	3.4
16/5/1997	29:07.8	33.1983N	60.2100E	15.8	3.7
17/5/1997	11:21.6	33.4916N	59.9816E	6.1	3.4
17/5/1997	24:59.8	33.4916N	59.9250E	10.7	3.5
17/5/1997	59:24.7	33.5050N	59.9716E	0.8	3.6
17/5/1997	07:43.6	33.4966N	59.9533E	0.2	3.4
17/5/1997	47:01.7	33.5531N	60.1233E	10.7	3.8
17/5/1997	33:30.2	33.0833N	59.9866E	0.6	3.7
17/5/1997	03:10.4	33.4900N	59.9650E	10.8	3.1
17/5/1997	07:30.7	33.5300N	59.9633E	0.7	2.9
17/5/1997	09:41.2	33.6090N	59.9416E	10.4	3
17/5/1997	45:08.0	33.74.2N	59.8950E	10.2	3.3
17/5/1997	03:36.2	33.6880N	59.9683E	0.2	3.1
17/5/1997	45:42.9	33.4045N	60.0133E	0.9	3.6
17/5/1997	33:59.4	33.4433N	59.9966E	10.2	3.5
17/5/1997	53:24.4	33.3500N	60.0150E	1.1	3.7
17/5/1997	59:13.6	33.7850N	59.8983E	10.9	3.2
17/5/1997	13:07.5	33.4333N	60.0583E	20.3	3.4
17/5/1997	30:44.7	33.9550N	60.0416E	0.6	3.5
17/5/1997	45:10.0	33.5066N	59.9066E	10	3.3
17/5/1997	15:30.8	33.5266N	59.9950E	0.1	2.7
17/5/1997	39:24.3	33.3750N	59.9983E	10.3	3.8
17/5/1997	54:56.0	33.3316N	60.0883E	16	3.4
17/5/1997	56:28.5	33.3183N	60.2683E	10.7	3.7
17/5/1997	40:40.0	33.6916N	59.9033E	0.8	3.1
17/5/1997	47:23.1	33.5283N	59.9800E	11.8	2.8
18/5/1997	27:16.2	33.5066N	59.9800E	0.4	3
18/5/1997	55:01.9	33.4933N	59.9750E	1	3.3
18/5/1997	15:58.6	32.9416N	59.9533E	19.7	3.6
18/5/1997	35:22.9	33.5016N	59.9950E	0.4	2.8
18/5/1997	20:49.8	33.5283N	59.9683E	0.1	2.3
18/5/1997	07:28.3	33.4966N	59.9866E	0.9	2.8
18/5/1997	36:45.6	33.0516N	59.8883E	0.3	3.7
18/5/1997	44:38.1	33.4300N	59.9683E	1	2.6
18/5/1997	23:19.6	33.4416N	59.9800E	1.2	2.8
18/5/1997	26:58.5	33.8333N	59.9600E	10	3
18/5/1997	52:22.6	33.4933N	59.9783E	0.5	2.8
18/5/1997	07:38.6	33.6916N	59.8633E	0.2	3.6
18/5/1997	08:01.9	33.5233N	59.9866E	10.2	2.9
18/5/1997	09:31.9	33.9183N	59.9850E	10.9	3.4
18/5/1997	41:19.1	33.6650N	59.8766E	10	2.5
18/5/1997	57:55.7	32.9613N	60.3083E	10	3.8
18/5/1997	45:01.7	33.6916N	59.9500E	0.8	3.1
18/5/1997	19:11.3	33.3366N	60.0483E	30.7	3.4
18/5/1997	52:31.5	33.6183N	59.9766E	0.9	2.2
18/5/1997	06:05.1	33.5150N	59.9866E	10.8	3
18/5/1997	41:15.9	33.5716N	59.9850E	8.6	3
18/5/1997	54:35.0	33.4966N	59.9950E	10.1	3
18/5/1997	05:24.6	33.4916N	60.0066E	11.9	3.5
18/5/1997	48:16.2	33.5416N	59.9250E	2	3
19/5/1997	08:24.9	33.8100N	59.9250E	13.2	2.7
19/5/1997	29:29.7	33.6916N	59.8833E	0.6	3.5
19/5/1997	20:18.7	33.4533N	59.9883E	0.2	2.9
19/5/1997	09:49.9	33.3816N	59.9650E	0.4	3.1
19/5/1997	08:10.5	33.1600N	59.8816E	0.1	3
19/5/1997	44:53.6	33.3716N	59.9866E	41.1	3.4
19/5/1997	14:12.9	32.8750N	59.7833E	12	3.5
19/5/1997	26:33.5	33.8483N	60.0100E	19.6	3.7
19/5/1997	15:45.0	33.8366N	59.9716E	11.2	3
19/5/1997	56:01.6	33.5866N	59.9950E	0.4	3
19/5/1997	13:23.1	33.3600N	60.0166E	14.7	3.3
19/5/1997	42:23.3	33.6916N	59.9250E	4.7	2.6
19/5/1997	55:10.5	33.6916N	59.9250E	7.2	3
19/5/1997	15:01.2	33.7333N	59.8866E	19.7	3.3
19/5/1997	16:01.5	33.9300N	59.9883E	21.1	3.4
19/5/1997	42:43.4	33.5000N	59.9616E	6.8	3
19/5/1997	57:38.4	33.5233N	59.9950E	7.6	3.4
19/5/1997	15:43.6	33.6050N	59.8200E	3.6	2.8
19/5/1997	20:48.3	33.7583N	59.8933E	19.2	3.1
20/5/1997	04:03.1	33.4666N	59.9966E	3.2	3.1
20/5/1997	15:05.5	33.4700N	59.9866E	4.1	3.1
20/5/1997	18:08.6	33.6133N	59.9150E	8.9	2.5
20/5/1997	24:54.8	33.5116N	59.9666E	5.4	2.7
20/5/1997	05:32.7	33.5050N	60.0000E	15.1	2.6

Appendix II. Continued ...

Date	Time	Lat.	Long.	Dep.	Mag.
20/5/1997	38:57.9	33.7400N	60.0916E	6.2	2.9
20/5/1997	01:48.2	33.8150N	59.8900E	12.7	3.3
20/5/1997	48:16.2	33.5033N	59.9833E	8.9	2.9
21/5/1997	30:03.8	33.6250N	59.8850E	9.6	2.7
21/5/1997	41:54.1	33.6416N	59.9250E	4	3
21/5/1997	51:43.9	33.6916N	59.8866E	5.7	2.8
21/5/1997	14:27.4	33.7050N	60.0166E	5	3.1
21/5/1997	06:48.0	33.5050N	59.9583E	8.6	2.7
21/5/1997	21:55.3	33.3133N	59.9733E	40.7	3.6
21/5/1997	35:47.1	33.4966N	59.9783E	8.8	2.8
21/5/1997	23:51.7	33.6916N	59.9250E	13.7	3.3
21/5/1997	04:54.5	33.6616N	59.9466E	6.3	2.5
21/5/1997	19:41.2	33.6783N	59.9450E	5.5	2.9
21/5/1997	15:31.6	33.3066N	60.0683E	15.8	3.5
21/5/1997	37:17.1	33.5116N	59.9650E	16.4	2.5
21/5/1997	56:50.6	33.3100N	60.2666E	15.9	3.9
21/5/1997	56:52.4	33.5050N	59.9866E	8.6	3
21/5/1997	53:01.7	33.6883N	60.0233E	11.8	4
21/5/1997	51:20.4	32.9150N	59.7833E	15.2	3.7
22/5/1997	01:17.3	33.2900N	59.9500E	32.6	3.4
22/5/1997	41:08.7	33.0516N	59.8883E	46.3	3.8
22/5/1997	44:08.6	33.0766N	59.7833E	6.9	3.9
22/5/1997	02:28.1	33.3583N	60.0700E	26.3	3.8
22/5/1997	33:36.7	33.3016N	59.9533E	42	3.6
23/5/1997	24:10.1	33.4283N	60.0866E	36.7	4
23/5/1997	30:26.0	33.6464N	59.8750E	7.1	3.5
23/5/1997	43:22.3	33.4900N	59.9850E	8.5	3
23/5/1997	14:03.4	33.5066N	59.9833E	16.6	3.2
23/5/1997	08:11.9	33.7750N	59.9216E	44.3	3.1
23/5/1997	13:18.5	33.7316N	59.8800E	19.6	3.3
23/5/1997	29:21.1	33.8566N	59.9466E	21.4	3.1
23/5/1997	58:05.4	33.4816N	59.9716E	9.1	3
23/5/1997	38:21.1	33.4800N	59.9733E	14.3	3.1
23/5/1997	00:11.2	33.4900N	59.9750E	8.9	3.5
23/5/1997	14:32.4	33.2533N	60.1883E	19.2	3.7
23/5/1997	45:05.1	33.3650N	60.0450E	22.1	3.9
23/5/1997	15:05.9	33.4883N	59.9783E	9.4	2.8
23/5/1997	46:29.6	33.2483N	60.1000E	13.5	3.6
24/5/1997	15:14.9	33.8600N	59.9450E	21.5	3.5
24/5/1997	28:46.1	33.8083N	60.1366E	10.7	4
24/5/1997	23:48.4	33.5333N	60.0150E	7.1	3.1
24/5/1997	39:33.8	33.7133N	59.9100E	14.5	2.6
24/5/1997	41:45.1	33.4233N	59.9733E	14.7	3.4
24/5/1997	50:09.3	33.8383N	60.1633E	14.8	3.5
24/5/1997	19:32.3	33.4300N	60.0233E	19.5	2.8
24/5/1997	37:39.2	33.7300N	60.0716E	6.3	3
24/5/1997	55:05.8	33.7413N	59.9256E	9.7	3.1
24/5/1997	25:18.2	33.6516N	59.9250E	5.1	3
24/5/1997	48:26.3	33.6650N	60.0066E	5.4	2.9
24/5/1997	13:18.5	33.6916N	59.9000E	21.7	2.9
24/5/1997	44:25.7	33.5466N	59.7150E	22.8	3.3
24/5/1997	24:36.4	33.4250N	60.0983E	15.6	3.7
24/5/1997	36:39.8	33.8515N	59.9256E	5	3.6
24/5/1997	24:38.4	33.2916N	60.0350E	12.9	3.4
24/5/1997	23:16.4	33.3550N	60.4016E	23.4	3.8
24/5/1997	52:58.6	32.9716N	60.3100E	33	3.9
24/5/1997	25:56.8	33.7300N	59.8583E	21.9	2.8
24/5/1997	29:53.8	33.5083N	59.9600E	9	3.5

Date	Time	Lat.	Long.	Dep.	Mag.
24/5/1997	28:06.7	33.5400N	59.9650E	8.3	2.9
24/5/1997	33:42.5	33.3150N	60.2816E	14.8	3.6
25/5/1997	44:44.2	33.6917N	60.0307E	3.1	3
25/5/1997	33:37.0	33.3097N	59.9630E	30.4	3.7
25/5/1997	24:00.2	33.3652N	59.9617E	23.7	3.2
25/5/1997	58:37.5	33.4865N	59.9787E	10.2	3.1
25/5/1997	13:23.4	33.3480N	59.9740E	10.5	3.5
25/5/1997	45:31.9	33.4668N	59.9458E	16	2.8
25/5/1997	58:51.7	33.3788N	59.9256E	0.1	3.3
25/5/1997	07:43.1	33.2412N	60.1975E	17.4	4.2
25/5/1997	11:10.0	33.6617N	60.0490E	2.9	2.5
25/5/1997	46:52.2	32.7668N	60.0395E	15.2	3.1
25/5/1997	57:56.9	33.6358N	59.8857E	10	3
25/5/1997	16:24.1	33.4693N	59.9855E	13.2	3.2
25/5/1997	29:37.6	33.6936N	59.8436E	21.4	3.5
25/5/1997	56:01.8	33.6917N	59.8955E	8.6	3.1
26/5/1997	06:23.2	33.3552N	59.9422E	19.1	3.4
26/5/1997	43:20.9	33.3542N	60.1543E	28.3	3.7
26/5/1997	54:23.4	33.5140N	59.9732E	9.5	2.9
26/5/1997	16:58.5	33.8575N	59.8903E	5.8	2.8
26/5/1997	36:23.3	33.4176N	59.9853E	10	3.5
26/5/1997	49:05.6	33.4335N	60.0258E	20.1	3
26/5/1997	59:09.9	33.6612N	59.9257E	8.6	3.1
26/5/1997	16:46.7	33.4880N	59.9777E	9.6	3.2
26/5/1997	25:46.8	33.5740N	60.0395E	6.7	3.2
26/5/1997	00:24.8	33.6917N	59.8910E	9.8	2.7
26/5/1997	48:07.1	33.6517N	59.8308E	10	3.9
26/5/1997	50:11.7	33.4330N	60.0047E	18.5	3.2
26/5/1997	24:29.7	33.0588N	60.0662E	26.3	3.9
26/5/1997	24:24.4	33.4670N	59.9917E	12.8	3.4
26/5/1997	57:25.0	33.3487N	60.0912E	23	3.9
26/5/1997	16:19.9	33.7846N	59.9298E	17.2	3.4
26/5/1997	28:42.5	33.2745N	60.0063E	25.3	3.3
26/5/1997	47:02.9	33.6022N	59.9257E	2.3	3.1
27/5/1997	37:33.9	33.4977N	59.9843E	13.3	3
27/5/1997	01:55.1	33.5117N	59.9665E	8.5	2.9
27/5/1997	02:51.0	33.4885N	59.9635E	14.1	2.5
27/5/1997	10:22.7	33.4928N	59.9768E	9.8	2.8
27/5/1997	45:28.2	33.4527N	59.8202E	12.6	2.7
27/5/1997	07:46.2	33.2855N	59.9515E	28.9	3.4
27/5/1997	06:19.0	33.4918N	59.9987E	14.6	3.5
27/5/1997	37:07.1	33.2000N	60.0890E	23.5	4
27/5/1997	25:23.2	33.7310N	59.8737E	5.1	3.2
27/5/1997	55:49.2	33.2420N	60.0705E	22.6	3.9
27/5/1997	19:44.7	33.5242N	59.9815E	8.9	3.3
27/5/1997	24:28.8	33.6088N	59.9282E	4.8	2.6
27/5/1997	45:37.9	33.8133N	59.9257E	14.9	3.4
27/5/1997	54:34.9	33.2280N	60.0763E	18.9	3.7
28/5/1997	04:59.2	33.5237N	60.0025E	11.8	3.1
28/5/1997	45:42.4	33.5682N	59.9752E	3.9	2.8
28/5/1997	15:10.5	33.3722N	60.0408E	19.7	3.5
28/5/1997	10:00.0	33.7418N	59.8925E	16.4	3.3
28/5/1997	30:14.7	33.4813N	59.9670E	14.7	3.1
28/5/1997	57:18.4	33.4237N	59.9947E	7.5	3.7
29/5/1997	39:15.5	33.2553N	60.1322E	22.1	3.6
29/5/1997	16:48.2	33.4250N	59.9963E	15.2	3.1
29/5/1997	47:43.9	33.3010N	59.8220E	10	3.1
29/5/1997	53:25.3	33.5668N	60.0230E	10.9	2.6

Appendix II. Continued ...

Date	Time	Lat.	Long.	Dep.	Mag.
29/5/1997	15:23.6	33.7675N	59.9180E	26.5	3.4
29/5/1997	48:56.4	32.9547N	60.0212E	32	3.9
30/5/1997	11:22.0	32.9908N	60.0098E	35.6	3.9
30/5/1997	36:51.6	33.7510N	59.8920E	7.6	3.4
30/5/1997	24:03.2	32.9775N	59.8867E	53.2	3.7
30/5/1997	29:43.1	33.4176N	60.0440E	10	3.5
30/5/1997	49:59.3	33.3168N	60.0315E	29	3.5
30/5/1997	22:54.1	33.3718N	60.0442E	20.9	3.8
30/5/1997	48:37.9	33.5090N	59.9978E	6.8	2.7
30/5/1997	00:39.7	33.2788N	60.1407E	21.2	3.3
30/5/1997	09:47.7	33.4925N	59.9647E	8.4	3.3
30/5/1997	23:17.5	32.8287N	59.9745E	25.6	4.3
30/5/1997	42:10.7	33.5255N	59.9353E	14.7	2.4
30/5/1997	44:08.7	33.6267N	59.8970E	10	2.6
30/5/1997	07:44.4	33.6698N	60.0655E	1.7	2.9
30/5/1997	27:43.9	33.4533N	60.0243E	12.6	3.2
30/5/1997	43:08.5	33.5338N	59.9888E	11.7	2.8
30/5/1997	10:25.4	33.0540N	59.9998E	11	2.6
30/5/1997	23:20.4	33.4908N	59.9695E	15.4	3.2
31/5/1997	28:16.0	33.2073N	59.6070E	43.5	3.7
31/5/1997	53:30.4	33.4176N	59.7836E	10	3.8
1/6/1997	50:28.2	33.7513N	59.6006E	0.1	3.6
1/6/1997	36:55.7	33.6500N	59.8770E	7.1	2.6
1/6/1997	31:31.3	33.3318N	59.9590E	27.7	3.3
1/6/1997	35:32.2	33.5040N	59.9712E	13.5	3.2
1/6/1997	16:36.3	33.5035N	59.9773E	6.6	2.9
1/6/1997	38:51.4	33.4953N	59.9515E	9.7	3
6/1/1997	01:52.0	33.7232N	59.8808E	18.3	3.2
2/6/1997	01:38.7	33.7238N	59.8898E	16.4	3.4
2/6/1997	17:16.1	33.7738N	59.9068E	27.2	3
2/6/1997	53:12.9	33.1050N	60.1867E	26.5	3.7
2/6/1997	16:02.1	33.4112N	59.9948E	19.7	3.5
3/6/1997	26:49.2	33.6917N	59.8570E	10	2.8
3/6/1997	35:16.0	33.5328N	59.9745E	11.8	2.9
3/6/1997	30:25.4	33.4242N	60.0275E	18.8	3.4
3/6/1997	38:46.7	33.4945N	59.9817E	8.9	3.8
3/6/1997	32:43.7	33.4176N	59.9881E	0.2	3.9
3/6/1997	19:56.3	33.2297N	60.0585E	26.7	3.1
4/6/1997	31:44.2	33.4958N	59.9528E	7.9	3.1
4/6/1997	59:33.7	33.4707N	59.9652E	15.6	3
4/6/1997	04:42.2	33.2137N	60.1767E	35.2	4
4/6/1997	23:45.4	33.6917N	59.9257E	5.1	3.1
4/6/1997	19:48.6	33.5298N	59.9697E	5	2.7
4/6/1997	25:56.5	33.5198N	59.9425E	6.4	3.2
4/6/1997	33:28.3	33.4983N	60.0205E	24.9	3
4/6/1997	38:57.7	33.6683N	59.8840E	8.6	2.8
4/6/1997	09:33.4	33.6990N	60.0267E	5.8	3.1
4/6/1997	35:30.9	33.3905N	60.1287E	19.4	3.4
6/6/1997	58:53.2	34.0098N	60.1082E	9	3.8
6/6/1997	57:06.3	32.7973N	59.9882E	10	3.8
7/6/1997	09:12.9	33.2943N	60.0948E	25.1	3.7
7/6/1997	07:48.6	33.5908N	59.8392E	3.2	2.5
7/6/1997	50:31.0	32.9987N	60.0760E	27.6	3.8
7/6/1997	03:59.8	33.4965N	59.9720E	8.5	3.3
7/6/1997	34:14.2	33.7930N	59.9698E	19.8	3.3
8/6/1997	34:17.5	33.6917N	59.9257E	5.1	2.9
8/6/1997	51:01.3	33.1432N	60.1022E	30.7	3.8
8/6/1997	19:08.7	33.6488N	59.9997E	9.2	2.8
8/6/1997	50:32.0	33.4987N	59.9828E	10.4	3

Date	Time	Lat.	Long.	Dep.	Mag.
8/6/1997	10:11.9	33.5972N	59.8925E	7.3	2.3
8/6/1997	30:00.0	33.6917N	59.9257E	5.1	2.6
8/6/1997	46:23.5	33.4967N	59.9717E	13.4	3.3
9/6/1997	42:44.2	33.5313N	60.0367E	5.2	3.7
9/6/1997	04:34.3	33.2600N	60.0003E	56.8	3.3
9/6/1997	36:41.0	33.4176N	60.0343E	0.1	3.3
9/6/1997	42:01.2	33.4015N	60.0428E	15	3.1
9/6/1997	44:50.7	33.5110N	59.9947E	8.3	2.7
9/6/1997	33:14.6	33.2620N	60.0737E	24.1	3.5
9/6/1997	01:08.8	33.5377N	59.9775E	12.8	3.3
9/6/1997	54:43.7	33.3018N	60.0403E	21.7	3.4
9/6/1997	00:28.8	33.4005N	59.9947E	8	3.6
9/6/1997	09:41.0	33.8277N	60.2207E	6.5	3.3
9/6/1997	14:44.9	33.4838N	59.9647E	8.1	3.3
9/6/1997	57:14.8	33.4893N	59.9987E	9.7	2.8
10/6/1997	00:38.7	33.2668N	60.0517E	24.8	3.7
10/6/1997	21:51.6	33.4962N	59.9790E	9.2	3.1
10/6/1997	32:52.9	33.7001N	59.9915E	10	3.8
10/6/1997	33:59.7	33.6845N	59.9912E	4.5	2.6
10/6/1997	51:14.7	33.3877N	60.0938E	19.9	3.5
11/6/1997	04:54.6	33.3445N	60.1315E	18.9	3.3
11/6/1997	47:25.4	33.4298N	59.8395E	13.7	3.2
11/6/1997	31:50.8	33.6917N	60.0305E	4.1	2.8
11/6/1997	49:49.5	33.7306N	60.0183E	0.3	2.9
11/6/1997	37:22.7	33.1905N	60.2547E	31.2	3.8
11/6/1997	20:07.6	33.4450N	60.0483E	16.1	3.4
11/6/1997	03:20.2	33.5067N	59.9700E	13.2	2.9
11/6/1997	03:51.2	33.9333N	60.0083E	12.7	2.9
12/6/1997	02:59.6	33.3067N	60.2133E	37	3.8
12/6/1997	08:54.4	33.6917N	59.9250E	10	3.2
12/6/1997	33:10.0	33.6917N	59.9250E	16.1	3.3
12/6/1997	21:26.5	33.1100N	60.2167E	47.6	3.6
12/6/1997	34:48.3	33.5068N	60.0171E	0.1	3
12/6/1997	18:47.4	33.4750N	59.9483E	18.9	2.4
12/6/1997	47:00.5	33.5000N	59.9850E	15.9	2.7
13/6/1997	01:59.9	33.7833N	59.8750E	25.2	3.7
13/6/1997	21:25.0	33.6917N	59.9250E	13.9	2.8
13/6/1997	57:17.7	33.3967N	60.1117E	35	3.8
13/6/1997	03:50.6	33.1667N	60.2367E	10	3.4
13/6/1997	32:25.9	33.4133N	60.0608E	27.7	3.3
13/6/1997	29:29.9	33.8883N	59.9250E	32.3	3.2
13/6/1997	10:28.5	33.5233N	59.9950E	11.8	3.1
14/6/1997	31:33.1	33.5150N	59.9717E	8.4	3.1
14/6/1997	58:05.3	33.8083N	59.9217E	24.2	3.4
14/6/1997	51:19.2	33.5967N	59.8250E	4.6	2.9
15/6/1997	04:09.5	33.6516N	60.0027E	10	2.9
15/6/1997	20:55.9	33.4917N	60.0067E	8.8	3
15/6/1997	54:48.1	33.0283N	60.0583E	27.8	3.6
15/6/1997	19:07.3	33.6233N	59.9200E	5.4	2.8
16/6/1997	33:33.3	33.0417N	59.9950E	5.1	3.9
16/6/1997	00:04.5	33.1956N	60.0005E	10	4.8
16/6/1997	35:48.9	33.4933N	59.9417E	7.3	2.7
16/6/1997	01:13.6	33.6917N	60.0417E	6.1	2.8
16/6/1997	34:51.2	33.4417N	59.9950E	9.9	3.2
16/6/1997	44:44.0	33.4483N	60.0542E	11.9	3.5
16/6/1997	25:18.0	33.4642N	60.0330E	11.4	2.9
16/6/1997	11:28.9	33.4083N	60.0283E	19.1	3.1
16/6/1997	47:17.1	33.4733N	60.0283E	10.2	3
16/6/1997	51:53.4	33.3400N	60.0650E	27.6	3.6

Appendix II. Continued ...

Date	Time	Lat.	Long.	Dep.	Mag.
16/6/1997	46:32.9	33.4417N	60.0583E	13.2	3.5
17/6/1997	43:44.9	33.4933N	60.0033E	7	2.8
17/6/1997	29:34.3	33.3333N	60.0792E	19.4	3.6
17/6/1997	03:43.5	33.5167N	59.9983E	5.3	3
17/6/1997	58:12.9	33.7083N	60.0767E	1.5	2.9
17/6/1997	14:43.0	33.3150N	60.1600E	13.5	3.5
17/6/1997	46:53.2	33.6517N	59.8800E	7.7	2.9
18/6/1997	00:15.4	33.3533N	60.0283E	24.7	3.4
18/6/1997	10:11.2	33.8183N	59.7517E	8.3	2.8
18/6/1997	04:28.2	33.3483N	60.0800E	25.1	3.6
18/6/1997	57:30.2	33.5367N	59.9800E	15.1	2.8
19/6/1997	45:13.9	33.4300N	60.1067E	14.5	3.4
19/6/1997	14:10.6	33.5150N	60.0317E	6.8	2.9
19/6/1997	23:22.5	33.4383N	60.0783E	16.3	3.3
20/6/1997	32:56.2	33.4650N	60.0417E	5.1	3.3
20/6/1997	54:46.0	33.4900N	59.9717E	7.6	3.1
20/6/1997	57:52.7	33.4183N	59.9233E	5.1	4.9
20/6/1997	25:15.8	33.3576N	59.9267E	10	4.3
20/6/1997	34:27.1	33.3055N	59.9969E	5.2	4.2
20/6/1997	30:52.9	33.6916N	59.9256E	11.1	4.1
20/6/1997	26:35.8	33.3382N	60.0987E	15.8	3.8
21/6/1997	45:25.9	33.3117N	60.0810E	20.2	4.3
21/6/1997	50:26.2	33.3100N	60.1017E	21.6	3.6
21/6/1997	33:37.8	33.7050N	59.9650E	1.3	3.2
21/6/1997	21:20.4	33.6050N	59.8650E	6.3	4.4
22/6/1997	46:34.4	33.5900N	59.8450E	2.6	2.6
22/6/1997	14:25.1	33.4917N	60.1217E	10.7	3.1
22/6/1997	40:56.9	33.6933N	59.8800E	27.3	3.1
22/6/1997	50:18.1	33.7283N	59.9017E	16.1	3.5
22/6/1997	52:53.7	33.3592N	60.1083E	25.7	4.5
22/6/1997	11:19.7	33.2900N	60.0550E	12.8	3.7
23/6/1997	06:58.3	33.6267N	59.8600E	12.8	2.9
23/6/1997	28:42.3	33.2100N	59.9950E	5.1	3.5
23/6/1997	49:02.4	33.6916N	59.9256E	14.6	3.8
23/6/1997	23:18.4	33.4850N	59.9217E	5	3.9
23/6/1997	57:22.6	33.5183N	59.9525E	8.3	2.7
24/6/1997	53:02.1	33.0273N	59.9256E	14.9	4.2
24/6/1997	45:26.6	33.4177N	60.0067E	16.3	3.3
24/6/1997	43:41.2	33.3583N	60.1250E	22.2	3.4
24/6/1997	18:56.5	33.4917N	59.9500E	6.3	2.8
24/6/1997	38:26.9	33.5142N	60.1467E	8.6	3.2
25/6/1997	42:35.7	33.6916N	59.9256E	5.4	4.3
25/6/1997	18:20.7	33.0317N	60.1275E	21.4	3.7
25/6/1997	38:46.9	33.6516N	59.8736E	10	5.3
25/6/1997	08:18.6	33.4983N	59.8948E	13.3	3.4
25/6/1997	28:30.9	33.4588N	59.8576E	9.6	3.7
25/6/1997	50:56.3	34.0043N	60.1016E	9.4	3.8
25/6/1997	15:39.7	33.5595N	59.9828E	28.4	3.4
26/6/1997	14:33.7	33.5017N	59.6952E	13.6	3.7
26/6/1997	22:46.1	33.6675N	59.9350E	24.5	3.3

Date	Time	Lat.	Long.	Dep.	Mag.
26/6/1997	49:53.4	33.6683N	59.6695E	28.2	3.4
26/6/1997	59:17.8	33.6523N	59.7536E	5.3	3.6
26/6/1997	46:09.8	33.6514N	60.0815E	10	4.1
26/6/1997	06:16.2	33.5236N	60.0646E	0.3	3.8
26/6/1997	39:31.4	33.4828N	59.9963E	6.9	2.8
26/6/1997	55:29.9	33.6617N	59.7536E	22.4	3.7
26/6/1997	55:22.9	33.6516N	60.1416E	10	3.4
26/6/1997	12:36.6	33.6517N	59.8467E	5.2	2.8
26/6/1997	00:39.6	33.4715N	60.0091E	23.5	3.3
26/6/1997	13:31.9	33.4333N	60.0085E	0.1	3.9
26/6/1997	59:47.4	34.0506N	60.0293E	0.1	3.6
26/6/1997	47:51.1	33.8100N	60.1267E	35.9	3.4
26/6/1997	55:45.7	33.8627N	59.9122E	39.9	3.7
26/6/1997	26:26.7	33.6516N	59.7536E	10	3.6
26/6/1997	43:49.8	33.9550N	59.8022E	18.7	3.6
26/6/1997	08:16.3	33.9783N	59.7745E	13.5	3.5
26/6/1997	47:36.3	33.8870N	60.0103E	5.1	3.1
27/6/1997	10:15.8	33.4733N	59.9788E	9.1	3.3
27/6/1997	04:52.5	33.8397N	59.9913E	38.8	3.6
27/6/1997	11:42.8	33.4050N	60.0516E	9.8	3.6
27/6/1997	10:28.7	33.2583N	60.1192E	25.3	3.6
27/6/1997	19:38.3	33.6916N	60.0596E	10	3.3
27/6/1997	38:49.8	33.4836N	59.8988E	0.1	3.6
27/6/1997	18:58.3	33.6918N	60.0583E	10	3.4
28/6/1997	57:05.0	33.4825N	60.0060E	13.8	2.6
28/6/1997	07:07.2	33.8100N	60.0428E	33	3.5
28/6/1997	01:06.4	33.4905N	60.0008E	10.9	3.4
28/6/1997	11:52.1	33.7870N	60.1177E	40.9	3.8
28/6/1997	13:42.0	33.6695N	60.0805E	1.2	2.9
29/6/1997	14:52.9	33.6916N	59.9256E	17.9	3.6
29/6/1997	55:16.2	33.2860N	60.0725E	22.9	3.5
30/6/1997	14:50.2	33.3750N	60.0433E	13.6	3.3
30/6/1997	07:12.6	33.6517N	59.8033E	12.4	3.6
30/6/1997	22:02.4	33.6915N	60.0604E	10	3.5
30/6/1997	17:42.6	33.5391N	59.8711E	0.1	3.6
30/6/1997	16:30.0	33.2368N	60.1205E	18.2	3.4
30/6/1997	57:51.3	33.6517N	59.8415E	0.1	2.9
30/6/1997	58:42.1	33.7180N	59.8932E	0.6	2.5
30/6/1997	17:26.2	33.5898N	60.0046E	0.1	3
1/7/1997	24:40.1	33.3050N	60.0732E	20.5	3.9
1/7/1997	35:42.2	33.5173N	59.9256E	8	3
1/7/1997	12:03.2	33.6917N	60.0642E	10	2.8
1/7/1997	31:56.3	33.3970N	60.0987E	8.3	3.4
2/7/1997	24:25.2	33.6415N	60.0335E	6	2.7
2/7/1997	31:52.0	33.8238N	60.0065E	36.2	3.3
2/7/1997	22:23.2	33.4900N	59.9947E	8.1	2.8
3/7/1997	06:46.0	33.9661N	60.0501E	0.3	3.4
3/7/1997	05:26.1	33.5843N	60.4790E	5.1	3.8
4/7/1997	08:28.8	33.4353N	59.9946E	5.2	3.6
4/7/1997	32:20.0	33.6517N	59.8035E	10	3.7