Epicenter and Magnitude (Righter scale) (courtesy by Ms.Sayoko Furuta, JMA) 15th Dec.2022

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Purpose: Learn how to locate the epicenter and calculate magnitude!

Read arrival times of P- and S-waves and maximum amplitudes from the seismograms recorded by the JMA-59 type seismographs, and determine the epicenter and earthquake magnitude (Rochter scale) from these values.

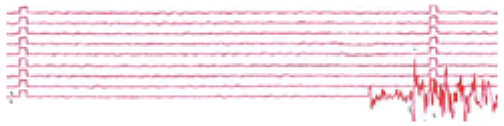
<Ref.1>. The JMA-59 type seismograph: standard seismograph for routine observations conducted by the Japanese Meteorological Agency (JMA) from the 1960's to 1990's using an analog recording system (see right figure).

Preparation: Ruler, Compass

Overview of seismograms:

Fig.1, 2 and 3 are displacement seismograms of an earthquake which occurred on June 28, 1994 in the Kinki district Japan. The seismograms were recorded by pen recorders of seismographs installed in Hikone, Osaka and Toyo-oka observatories, respectively.

Each seismograph recorded three components (NS, EW and UD) of a ground motion: NS indicates north-south, EW indicates east-west and UD indicates up-down.



Seismograms were recorded from left to right in chronological order. And also continues to next line.

The right figure marls are stamped every minute. The time mark span is 60 mm and then 1 mm of the record corresponds to 1 second. Also the amplification of seismograms is just 100 times. So the 1mm amplitude on a seismogram corresponds to 0.01mm ground motion.

Procedure:

Step 1.

Read arrival times of P- and S-waves by 0.1 second in Fig.1, 2 and 3 and write them down in Table 1.
It will be easier to work using a ruler. The time with a mark (○) is for reference.
Pick P-wave arrival in the vertical (UD) component and pick S-wave in the horizontal (NS and EW) components.
The arrival time of the S-wave should be read the earlier pick between the two components.

Step 2.

Read maximum amplitudes of horizontal (NS and EW) components by 0.1 mm and write them down in Table 1.

Step 3.

Calculate each duration of preliminary trends of the earthquake (S-P time): T sec. and calculate each hypo-central distance: D km in Table 1. Round them off to a decimal place and write them down in Table 1. The Omori coefficient k is fixed to 8.75 here.

Step 4.

Obtain each amplitude of three seismograms: A mm from the maximum half-amplitudes of the two components (NS and EW) in order to determine magnitude: M. To be simple, obtain this value by drawing a figure: halve the maximum amplitudes read in Step 2 and draw a right triangle whose sides adjacent to the right angle are of lengths of the maximum half-amplitudes (see Fig.4).
Read the value of A using a ruler, and write them down to a decimal place in Table 1.

<Ref.2.>

The formula to calculate M in this exercise is $M = \log(A) + 1.73 * \log(D) - 0.83$; this is used by JMA for earthquakes shallower than 61 km (Tsuboi, 1954).
The term A is the maximum horizontal amplitude obtained from the two components (NS and EW).

Step 5.

Draw three circles from each observation station at its center and with a radius of the hypo-central distance D and find the location of the epicenter, as shown in Fig.5.

<Ref.3>

Three or more common chords that link the points of intersection of the circles with a radius of the hypo-central distances always intersect at a point. This is the epicenter.

Step 6.

Fig.6 is a nomogram, which shows the logarithmic scale of amplitude A on the left, the logarithmic scale of hypocentral distance D on the right and the scale of magnitude M between them. A value of M at an intersection of the scale of M and a line connecting points of A and D becomes a magnitude of an earthquake with the amplitude A at a location with the hypo-central distance D.
Draw a line for the earthquake and read a magnitude for each observation station. Write the values in Table 1.

Let's consider the following discussions.

1) Compare the location of the epicenter determined in this exercise and the epicenter determined by JMA.
2) Let the value of a magnitude of the earthquake in this exercise be the average of the three magnitudes in Table 1. Write the value in the right ( ) and compare with the value determined by JMA ( ).
3) Use the nomogram and see how the magnitude changes with 10 times of D while keeping A. Also, see how it changes with 1/10 of A keeping D fixed.

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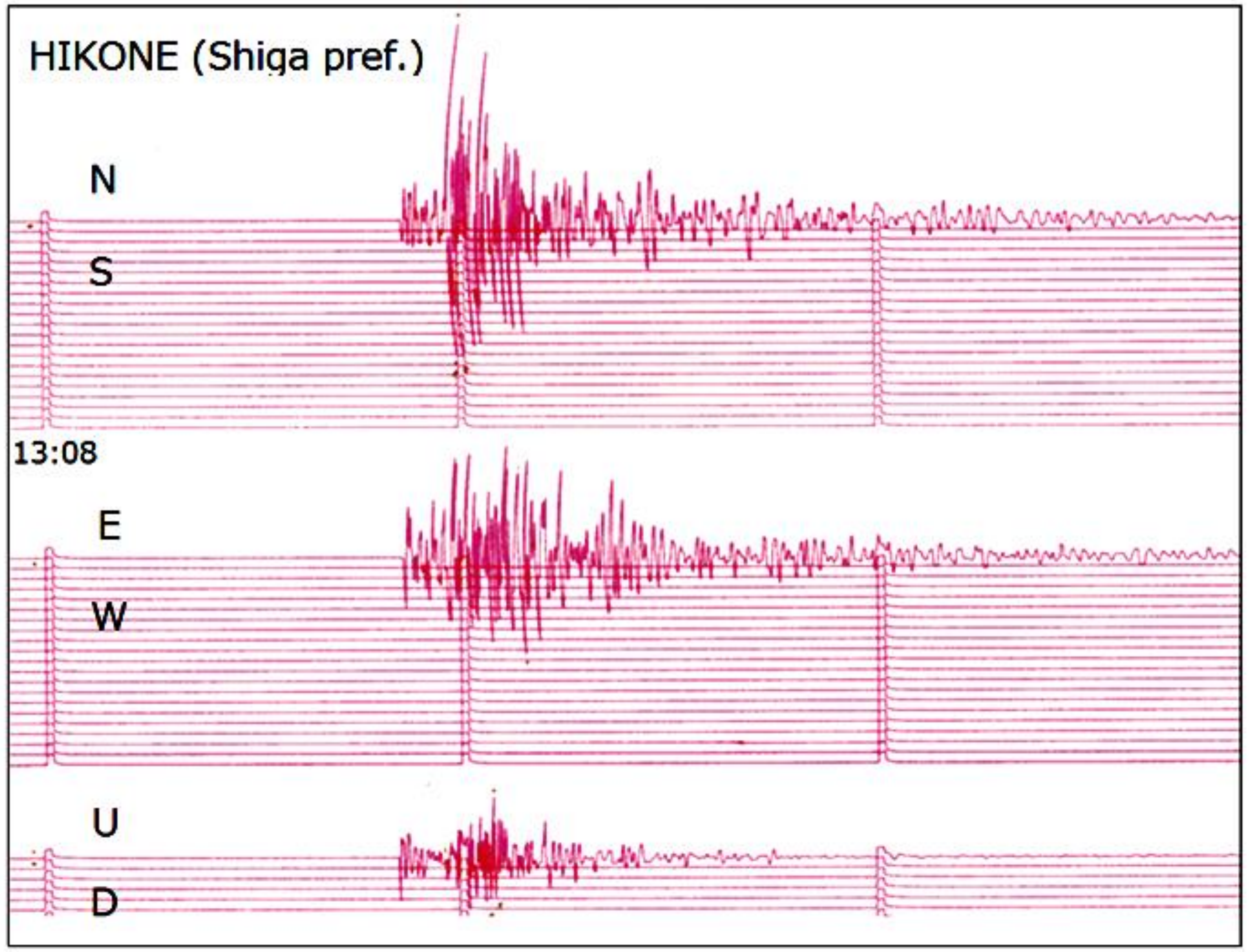
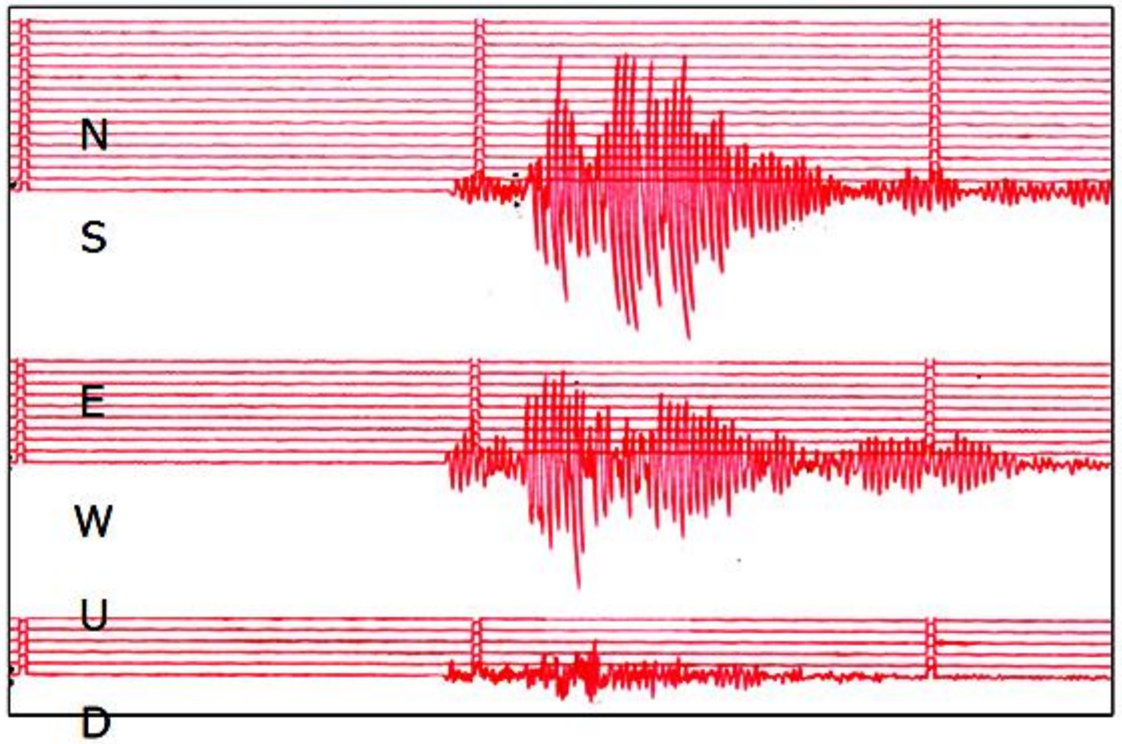
59type horizontal Seismographs in my house

Table 1 : Values to obtain in this exercise

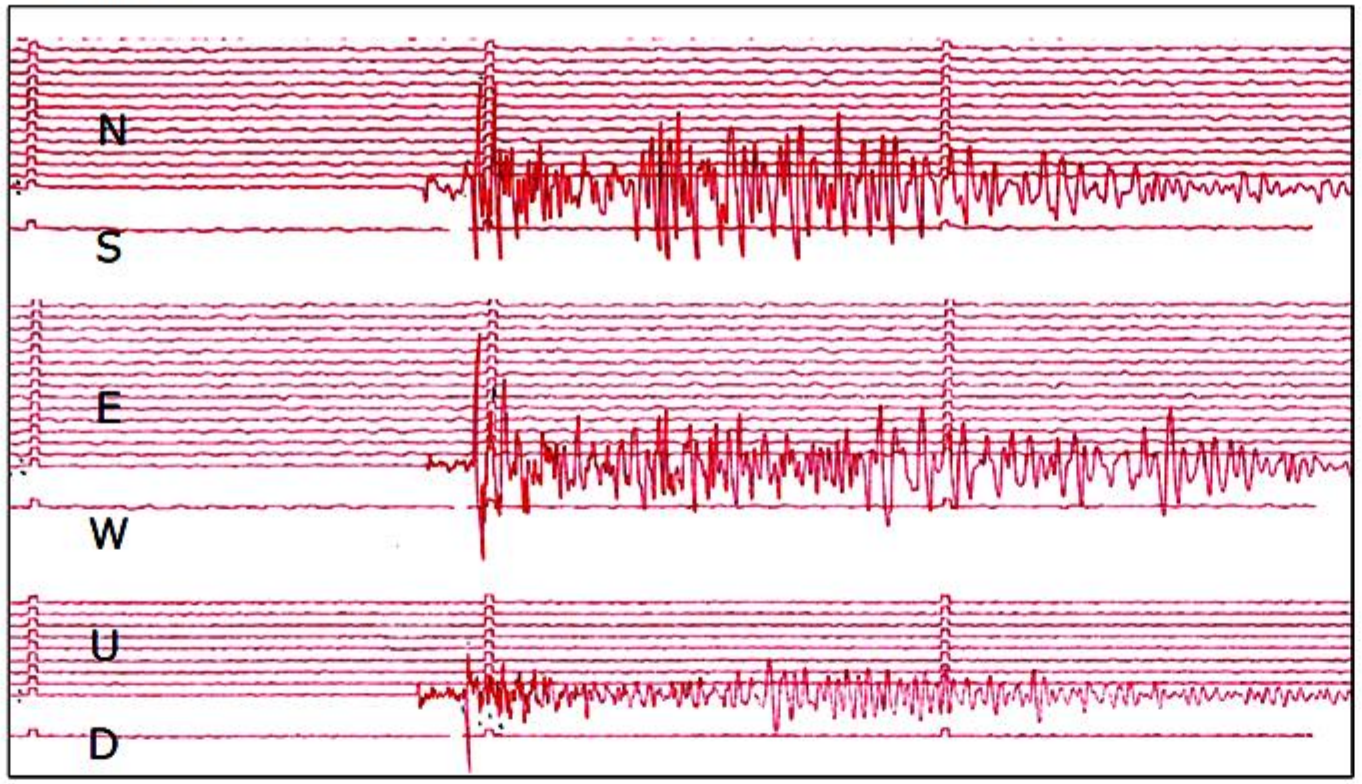
	HIKONE	OSAKA	TOYO-OKA	
A arrival time of P-wave				No need
A arrival time of S-wave				No need
S-P time : T				Only this need!
A hypocentral distance: $D = k \times T$ (k = 8.7)				k=8.75 is correct.
Maximum amplitude (NS)				Write in the seismogram
Maximum amplitude (EW)				//
Maximum half-amplitude (NS)				//
Maximum half-amplitude (EW)				//
Amplitude : A				
Magnitude				

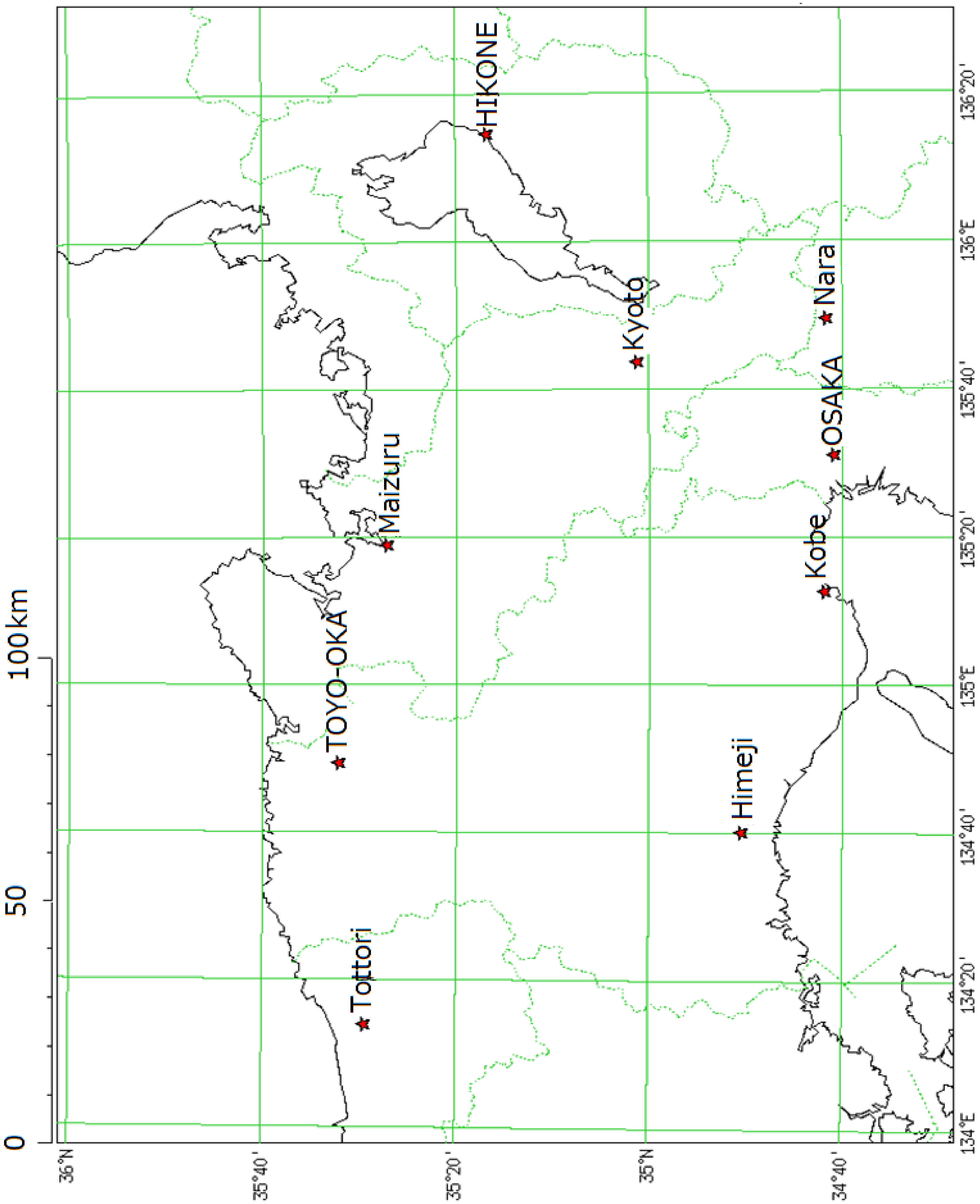


TOYO-OKA (Hyogo Pref.)



OSAKA





$$M = log(A) + 1.73 * log(D) - 0.83$$