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Historical Maximum Seismic Intensity Maps in Japan from 1586 to 2004: Construction of Database and Application

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Synopsis

We map the recorded maximum seismic intensity for earthquakes in Japan from 1586 to September 2004 using compiled historical records and Japan Metrological Agency (JMA) intensity data. We used a total of 337 events that had JMA intensity level of 4 or greater. The regions with high intensities are located along the Pacific coast side, reflecting the recurrent large inter-plate earthquakes. Also onshore, we find patchy high intensity regions due to earthquakes on onshore active faults. During the last 400 years, about 90% of the regions in Japan have experienced JMA intensity equal to or greater than 5- and 30% of the regions have had intensities equal to or larger than 6-.

Keywords: JMA intensity, intensity map

1. Introduction

Investigations of seismic intensities from historical earthquakes are useful for characterizing the damaging ground motions that have occurred in the past. Past studies have used these data to quantify the level of strong shaking for Japan. Kawasumi (1951) used relations between intensity, magnitude, and acceleration to estimate expected maximum acceleration levels across Japan for periods of 75, 100 and 200 years. Kanai and Suzuki (1968) in a similar method, estimated peak velocity distributions. Also in a related effort, Wesnousky et al.(1984) produced maps of Japan that show the probabilistic occurrence of earthquakes that have intensity equal to or larger than Japan Metrological Agency (JMA) intensity 5, from the distribution of active faults.

In this study, we take a simple approach of directly mapping the maximum historical intensity distribution across Japan. We use JMA intensity, as recorded by JMA and interpreted by Usami (2003). We make no assumptions about the magnitude-intensity relations or earthquake occurrence models. This approach is one of the most direct ways of looking at the past history of strong shaking across Japan and should show the actual historical intensity, including some local site effects. Since these are the results of the past earthquakes, the distributions will be different from the expected intensities from future earthquakes. However, our results should be useful for comparison with the probabilistic intensity maps for seismic hazard, which are being developed by the Headquarters for Earthquake Research Promotion (2003, 2004) using recent models of earthquake occurrence and ground motion attenuation relations. Also, these our maps are similar to the results of other intensity studies, such as Usami et al.(1999) and Nakamura et al.(2002).

2. Data and Methodology

We use intensity data for about the past 400 years, from 1586 to September 2004. Before 1926 we refer to the historical intensities compiled by Usami (2003). We choose 80 events which clearly show the distribution of observation locations. Since 1926 JMA has consistently recorded intensity distributions, however there has been a recent change in the JMA scale in 1996. At that time intensity levels 5 and 6 were both split into 2 levels. Intensity 5 became 5 Lower (5-) and 5 Higher (5+) and intensity 6 became 6 Lower (6-) and 6 Higher (6+). We transfer the old intensities into the present JMA seismic intensities by assuming a lower estimation, for example the former intensity scales 5 and 6 are converted to 5- and 6-, respectively, in present scale. We also interpret the (5-, 5+, 6-, 6+) designations by Usami (2003) for historical earthquakes directly in terms of the new JMA intensities. We use 257 earthquakes which had maximum intensity equal to or larger than 5, for the period from 1926 to September 2004. Hence, we use a total of 337 events (Table 1 in appendix). The epicenters of the earthquakes used are shown in Fig.1 and histograms of event magnitudes and number of events per 10 years in Fig.2. The locations and magnitudes for historical events are taken from Usami (2003). Clearly, for recent times, there are a much large number of earthquakes because of the increased quality of earthquake monitoring in Japan.

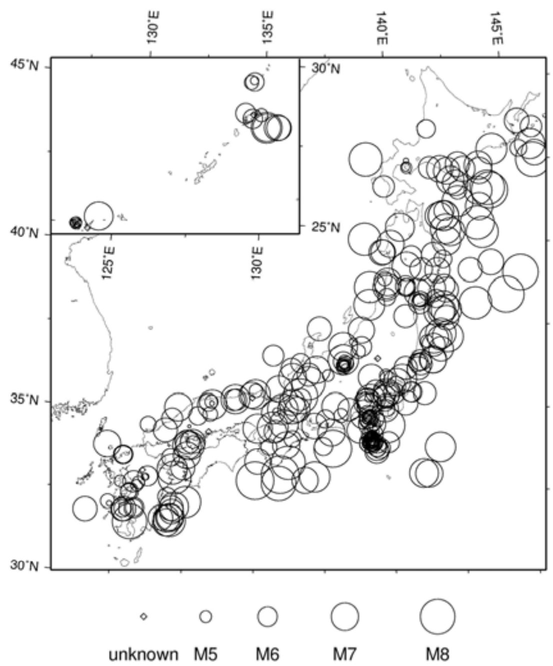

Fig. 1 Epicenters of earthquakes from 1586 to September 2004 used in this study.

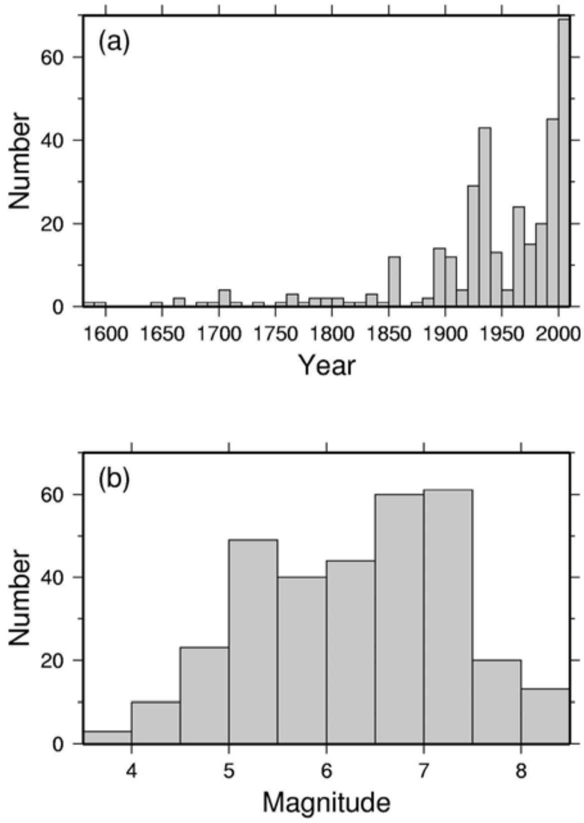

Fig. 2 Histograms of (a) decadal numbers and (b) magnitude for earthquakes in this study.

For each event, we construct an intensity distribution, with the following procedure using the available intensity data. We intend to use neither epicentral distance nor magnitude of the earthquake to avoid the specific model dependence. An intensity *I(x)* at an arbitrary point *x* (except for the observation point), is given by linearly interpolating the intensities at *n* surrounding locations nearest to *x* as

$$I(x) = \sum_{i=1}^{n} \left(\frac{1}{\Delta_i} \Big/ \sum_{j=1}^{n} \frac{1}{\Delta_j} \right) I_i \qquad (1)$$

where I_i is the recorded intensity at x_i and Δ_i is distance from x_i to x. To remove the probable bias, in which x is not be surrounded by $x_1, \ldots, x_n$, which could result in inappropriate interpolations, we use the following condition for the choice of x and x_i. For the n observation points located in polar coordinates with origin x and the location of x_i characterized by distance Δ_i and angle θ_i, the angle between neighboring observation points should be less than π. The n observation points are chosen in order of small Δ_i, where the maximum angle $\Delta\theta$ between neighboring observation points takes as small a value as possible. In a schematic diagram shown in Fig. 3, an arbitrary x satisfying this condition is in the shaded region. At point x_a in the shaded area, the intensity is calculated, while at x_b, outside the shaded region, the intensity is not calculated.

Grid points x are taken in 2^{-4} degree interval in both longitude and latitude. We use n=5 and show JMA intensity level of 4 or greater in the following examples.

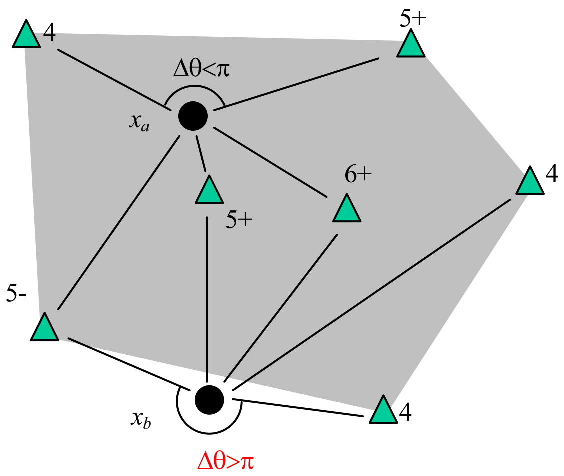

Fig. 3 Area in which intensities are calculated. Values of the observed intensities are indicated next to the stations (triangles). At point x_a in the shaded area, the intensity is calculated using eq.(1), where $\Delta\theta$, the maximum angle between neighboring observation points, is less than π. At x_b of $\Delta\theta > \pi$, the intensity is not calculated.

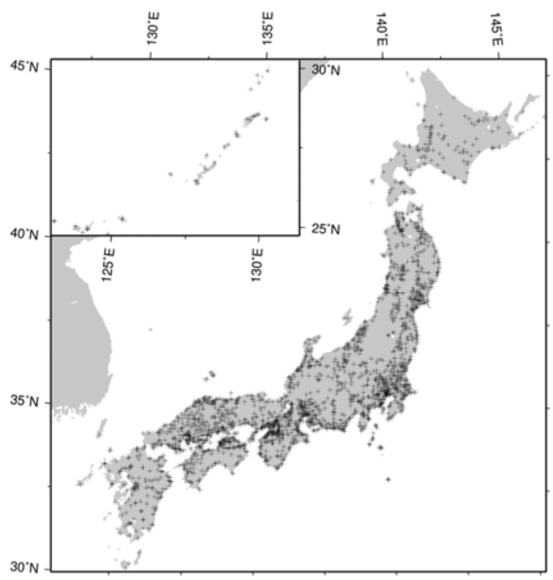

Fig. 4 Locations of 2235 observation stations.

3. Intensity Maps

The composite maximum intensity maps are obtained by taking the maximum intensity at every point from the intensity maps of each individual earthquake. The number of observation stations used in this study is 2235 and the locations are indicated by crosses in Fig.4.

3.1 The Maximum Intensity maps

Figure 5(a) shows the recorded maximum intensity map for earthquakes from 1586 to September 2004, which corresponds to a maximum intensity map for 400 years. The color pattern clearly shows the pattern of recorded maximum intensity across Japan. White regions indicate areas where there are incomplete data. Along the Pacific coast from Kyushu to Hokkaido, we find high intensity regions, compared to the Japan Sea coast. This pattern is caused by the large inter-plate large earthquakes associated with the subduction of the Philippine Sea plate and the Pacific Sea plate. This is more clearly seen in Fig.5(b), which shows the recorded maximum intensity from earthquakes which are thought to have occurred along the plate boundary and within the subducting slabs along the east and south coasts of Japan. Figure 5(b) also indicates that most areas along the Pacific coast side recorded intensities equal to or larger than 5+. Figure 5(c) shows the intensity distribution for all other events, not included in Fig.5(b), such as earthquakes associated with onshore active faults, volcanic events, back-arc basin earthquakes, and other events with unknown mechanisms. The patchy high intensity regions due to the events having long recurrence intervals appear all around Japan and are especially prominent around central Japan. The recorded maximum intensity for 100 years (from 1901 to 2000) is shown in Fig.5(d).

Figure 6(a) and (b) are histograms of the areas of different intensity-levels obtained from Fig.5(a) and (d). In the last 400 years in Japan, about 90% of the regions have recorded intensity equal to or larger than 5- and about 30% of the regions have recorded intensities equal to or larger than 6-. In 100 years (1901-2000), about 75% regions have experienced intensity equal to or larger than 5-.

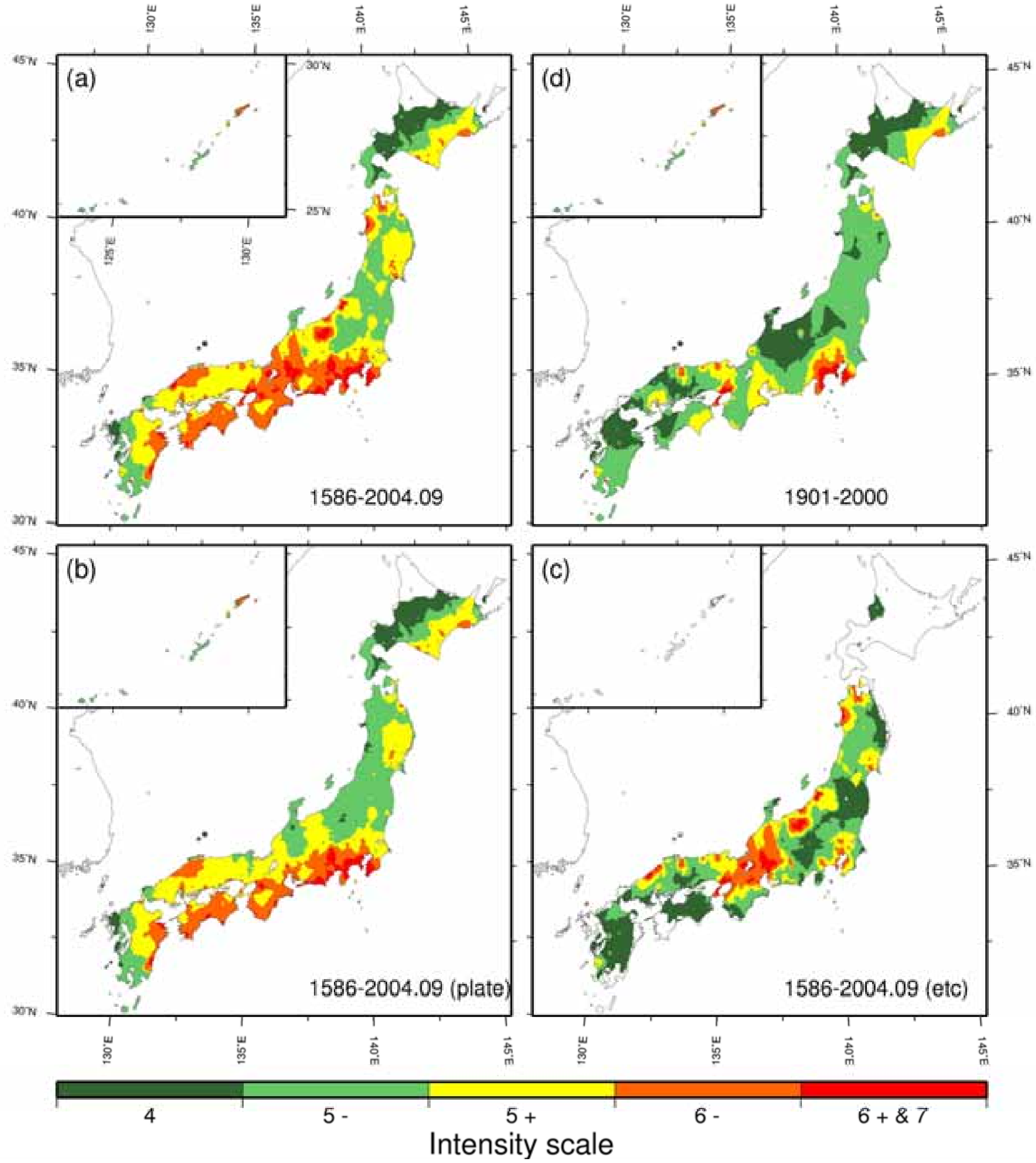

Fig. 5 Recorded maximum intensity maps. (a) 1586 to September 2004 includes intensities due to all selected earthquakes. (b) Earthquakes in inter-plate regions and within the subducting slabs. (c) Other events (e.g. earthquakes on onshore active faults, volcanic events, back-arc basin earthquakes). (d) 1901 to 2000.

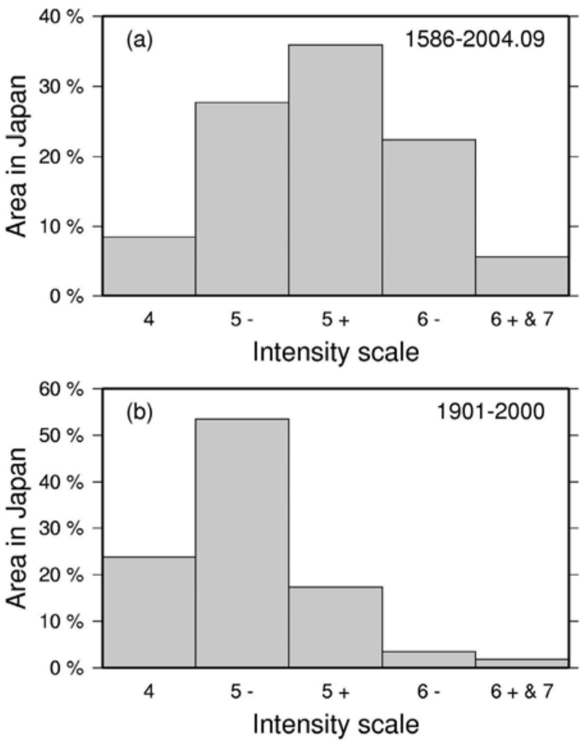

Fig. 6 Area distribution of maximum intensity (a) and (b) for Fig.5(a) and (b), respectively.

3.2 Tonankai & Nankai earthquakes

During the last 400 years, recurrent great interplate events occurred in the Tonankai and Nankai regions,. In 1707 (Hoei) the whole length ruptured in a single earthquake, while in 1854 (Ansei), and 1944, 1946 (Showa) there were two earthquakes that occurred closely together. Figure 7 shows a comparison of the intensity pattern for these 3 sequences. These intensity patterns show that repeats of the same earthquake may produce significantly different patterns of strong shaking.

3.3 The Tokaido and San'yo Shinkansen Lines

Figure 8 shows the maximum historical intensities along the Tokaido and San'yo Shinkansen lines. Most regions along the Tokaido Shinkansen line in the eastern part around from 135.5E to 139.8E, have experienced intensities equal to or larger than 6-. Regions along the Sanyo Shinkansen line in western Japan, around from 130.5E to 135.5E, have experienced intensities of 5+.

We showed the differences of intensity maps for 400 and 100 years in Fig.5(a) and (c), however, the Shinkansen lines have actually never experienced such large intensities as shown in Fig.8 since the Tokaido Shinkansen line was recently established in 1964 and the San'yo Shinkansen line in 1972 (1975 for the westernmost part).

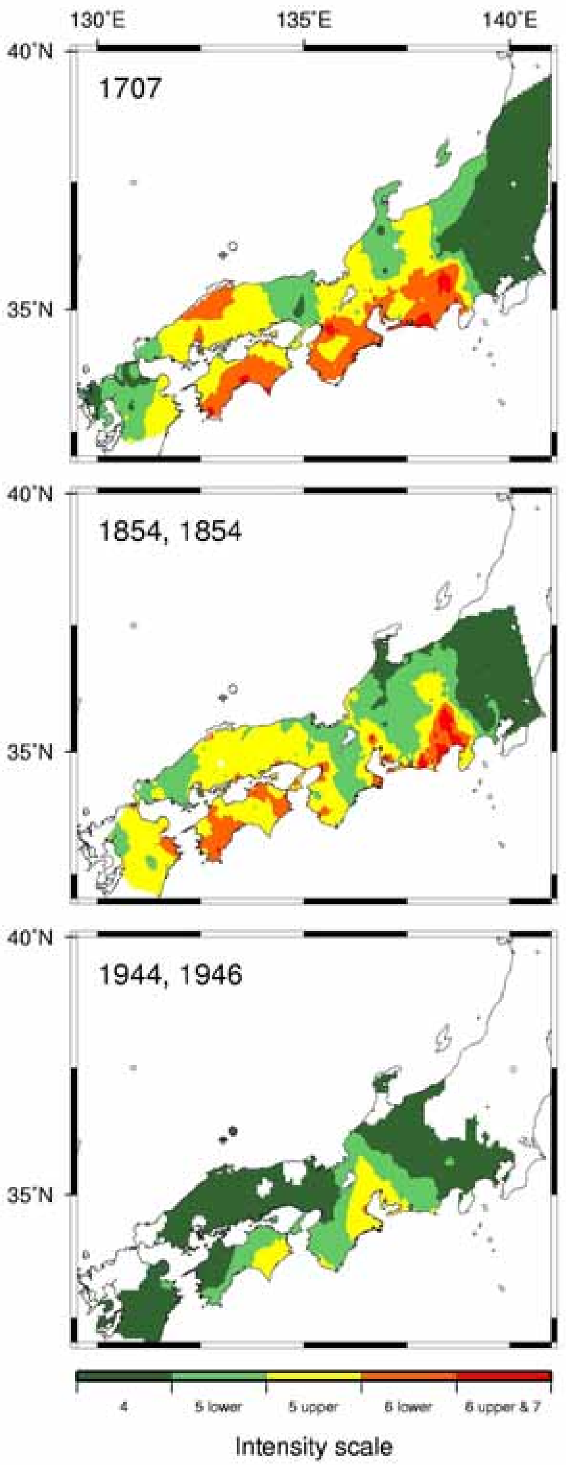

Fig. 7 Comparison of intensity distribution for three Tonankai and Nankai earthquakes.

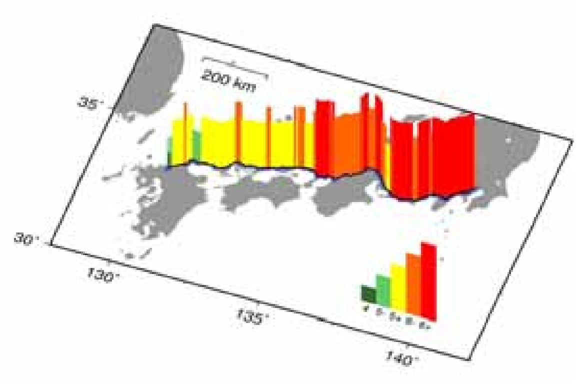

Fig. 8 Maximum intensity along the Tokaido and San'yo Shinkansen lines.

4. Discussion and Conclusions

The data for this time period of the last 400 years is thought to be largely complete, but it can be seen that 100 years of observations are not long enough to adequately characterize the seismic history.

There may be some problems in these historical intensity maps because it is difficult to recover the actual intensity due to the biases of observation (population) locations, incomplete historical documents, and problems of the interpolation. However, since we do not use any model assumptions (such as, intensity/magnitude relations or distance attenuation relations), these maps may provide one of the most direct results of the record of strong ground motions in Japan over the last 400 years.

Acknowledgements

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Appendix

Appendix-1

Table 1 Earthquakes

yyyy/mm/dd	magnitude (JMA)	lon. [deg]	lat. [deg]	depth [km]
1586/01/18	7.8 ± 0.1	136.9	36.0	-
1596/09/05	7.5 ± 0.25	135.6	34.65	-
1649/03/17	7.0 ± 0.25	132.5	33.7	-
1662/06/16	7.25-7.6	135.95	35.2	-
1662/10/31	7.5-7.75	132.0	31.7	-
1686/01/04	7.0-7.4	132.6	34.0	-
1694/06/19	7.0	140.1	40.2	-
1700/04/15	7.0	129.6	33.9	-
1703/12/31	7.9-8.2	139.8	34.7	-
1706/01/19	5.75 ± 0.25	139.9	38.6	-
1707/10/28	8.4	135.9	33.2	-
1718/08/22	7.0 ± 0.25	137.9	35.3	-
1731/10/07	6.5	140.6	38.0	-
1751/05/21	7.0-7.4	138.2	37.1	-
1763/01/29	7.4	142.25	41.0	-
1766/03/08	7.25 ± 0.25	140.5	40.7	-
1769/08/29	7.75 ± 0.25	132.1	33.0	-
1772/06/03	6.75 ± 0.5	141.9	39.35	-
1780/07/20	6.5	139.9	38.9	-
1782/08/23	7.0	139.1	35.4	-

1793/02/17	8.0-8.4	144.5	38.5	-
1799/06/29	6.0 ± 0.25	136.6	36.6	-
1802/11/18	6.5-7.0	136.5	35.2	-
1804/07/10	7.0 ± 0.1	139.95	39.05	-
1819/08/02	7.25 ± 0.25	136.3	35.2	-
1828/12/18	6.9	138.9	37.6	-
1830/08/19	6.5 ± 0.2	135.6	35.1	-
1833/05/27	6.25	136.6	35.5	-
1833/12/07	7.5 ± 0.25	139.25	38.9	-
1847/05/08	7.4	138.2	36.7	-
1853/03/11	6.7 ± 0.1	139.15	35.3	-
1854/07/09	7.25 ± 0.25	136.0	34.75	-
1854/12/23	8.4	137.8	34.0	-
1854/12/24	8.4	135.0	33.0	-
1854/12/26	7.3-7.5	132.0	33.25	-
1855/03/18	6.5	136.9	36.25	-
1855/11/07	7.0	137.75	34.5	-
1855/11/11	6.9 ± 0.1	139.8	35.65	-
1856/08/23	7.5	142.25	41.0	-
1857/10/12	7.25 ± 0.5	132.5	34.0	-
1858/04/09	7.0-7.1	137.2	36.4	-
1859/01/05	6.2 ± 0.2	131.9	34.8	-
1872/03/14	7.1 ± 0.2	132.1	35.15	-
1880/02/22	5.5-6.0	139.75	35.4	-
1889/07/28	6.3	130.65	32.8	-
1891/10/28	8.0	136.6	35.6	-
1894/03/22	7.9	146.0	42.5	-
1894/06/20	7.0	139.8	35.7	-
1894/10/07	6.7	139.8	35.6	-
1894/10/22	7.0	139.9	38.9	-
1895/01/18	7.2	140.4	36.1	-
1896/06/15	6.8	144.0	39.5	-
1896/08/31	7.2 ± 0.2	140.7	39.5	-
1897/01/17	5.2	138.25	36.65	-
1897/02/20	7.4	141.9	38.1	-
1897/08/05	7.7	143.3	38.3	-
1898/08/10	6.0	130.2	33.6	-
1898/08/12	5.8	130.2	33.6	-
1899/03/07	7.0	136.1	34.1	-
1900/05/12	7.0	141.1	38.7	-
1900/11/05	6.6	139.4	33.9	-
1901/01/14	6.8	143.8	42.3	-
1901/06/24	7.5	130.0	28.0	-
1901/08/09	7.2	142.5	40.5	-
1901/08/10	7.4	142.3	40.6	-
1904/03/18	6.8	146.1	42.7	-
1904/05/08	6.1	138.9	37.1	-
1905/06/02	6.7	132.5	34.1	-
1905/12/23	5.9	141.8	38.5	-
1907/07/06	6.7	145.5	43.7	-
1909/08/14	6.8	136.3	35.4	-
1911/06/15	8.0	130.0	28.0	-
1914/01/12	7.1	130.6	31.6	-
1914/05/23	5.8	133.2	35.35	-
1918/06/26	6.3	139.1	35.4	-
1921/12/08	7.0	140.2	36.0	-
1922/04/26	6.8	139.75	35.2	-
1923/09/01	7.9	139.3	35.2	-
1924/01/15	7.3	139.2	35.5	-
1925/05/23	6.8	134.8	35.6	-
1926/06/12	-	130.93	33.17	-
1926/07/04	-	129.5	28.38	-
1926/08/03	6.3	139.73	35.59	57
1927/03/07	7.3	134.93	35.63	18
1927/03/07	-	134.82	35.53	-
1927/03/07	-	134.82	35.53	-
1927/03/12	5.2	134.94	35.74	14
1927/08/06	6.7	142.17	37.9	25
1927/10/11	5.9	140.99	36.57	35
1927/10/18	5.3	129.77	32.16	9
1928/01/01	-	139.50	36.73	0
1928/02/12	-	139.50	36.73	0
1928/02/20	5.4	133.28	34.99	64
1928/02/28	-	-	-	-
1928/05/21	6.2	140.07	35.67	75
1928/06/01	6.6	143.18	39.31	45
1928/06/03	6.6	128.99	31.88	0
1928/09/25	5.8	131.92	33.60	76
1928/10/24	-	133.25	34.45	0
1929/05/20	3.9	132.54	34.59	65
1929/05/22	6.9	131.89	31.75	59
1929/07/17	5.2	139.80	36.20	65
1929/07/27	6.3	139.09	35.51	37
1929/12/22	-	139.50	36.73	0
1930/03/03	4.5	139.06	34.94	2
1930/03/09	4.9	139.11	34.98	0
1930/03/15	4.8	139.06	34.90	6
1930/03/22	5.9	139.10	35.04	10
1930/03/27	5.2	139.14	34.99	10
1930/05/09	4.7	139.19	34.89	26
1930/05/17	5.8	139.13	34.90	13
1930/05/24	-	139.50	36.73	0
1930/05/24	6.3	139.84	34.18	110
1930/05/29	-	139.50	36.73	0

1930/06/01	6.5	140.54	36.42	54	1953/11/26	7.4	141.72	33.98	60
1930/10/17	6.3	136.26	36.42	10	1958/03/11	7.2	124.50	24.75	80
1930/11/26	7.3	138.98	35.04	1	1958/11/07	8.1	148.50	44.30	80
1930/12/21	5.9	132.83	34.92	13	1961/02/27	7.0	131.89	31.64	37
1931/03/04	5.1	141.38	37.21	17	1962/04/23	7.1	143.77	42.46	69
1931/06/17	6.3	139.40	35.75	57	1962/08/26	5.9	139.41	34.12	33
1931/09/21	6.9	139.25	36.16	3	1962/08/30	5.2	139.39	34.16	20
1931/11/02	7.1	132.00	31.79	28	1963/03/27	6.9	135.80	35.81	14
1931/12/21	5.5	130.49	32.48	0	1964/06/16	7.5	139.22	38.37	34
1931/12/22	5.6	130.50	32.50	15	1966/01/23	5.1	138.22	36.52	0
1931/12/26	5.8	130.53	32.49	17	1966/02/07	4.9	138.22	36.50	0
1932/11/26	6.9	142.47	42.35	66	1966/03/13	6.6	122.67	24.24	42
1933/02/06	4.4	131.03	32.96	11	1966/04/05	5.4	138.32	36.58	0
1933/02/97	4.4	131.06	32.97	0	1966/04/11	4.7	138.20	36.57	0
1933/03/03	8.1	145.12	39.13	0	1966/04/17	4.7	138.23	36.53	0
1935/07/11	6.4	138.40	35.20	10	1966/04/17	4.7	138.25	36.55	0
1935/07/17	5.5	131.03	34.58	20	1966/04/17	4.7	138.28	36.43	0
1935/07/19	6.9	141.59	36.63	30	1966/05/28	5.3	138.22	36.57	0
1936/01/08	4.5	135.73	35.13	8	1966/08/03	5.3	138.20	36.47	0
1936/02/21	6.4	135.70	34.52	18	1967/10/14	5.3	138.20	36.53	10
1936/11/03	7.4	142.07	38.26	61	1968/02/21	5.7	130.72	32.02	0
1937/01/27	5.1	130.82	32.78	9	1968/02/21	6.1	130.72	32.02	0
1937/07/27	7.1	142.00	38.12	56	1968/04/01	7.5	132.53	32.28	30
1937/10/26	4.2	129.83	32.09	5	1968/05/16	7.9	143.58	40.73	0
1938/01/12	6.8	135.07	33.58	0	1968/05/16	7.5	142.85	41.42	40
1938/05/23	7.0	141.58	36.65	0	1968/08/06	6.6	132.38	33.30	40
1938/09/22	6.5	141.02	36.40	30	1968/09/21	6.8	142.80	41.98	80
1938/11/05	7.5	142.18	37.33	30	1970/01/01	6.1	129.22	28.4	50
1938/11/05	7.3	141.65	37.28	30	1970/01/21	6.7	143.13	42.38	50
1938/11/06	7.4	141.92	37.43	0	1970/07/26	6.7	132.03	32.07	10
1939/05/01	6.8	139.75	39.94	2	1971/08/02	7.0	143.70	41.23	60
1939/05/01	6.7	139.80	39.95	0	1972/02/29	7.0	141.27	33.18	70
1939/06/23	-	139.50	36.73	0	1972/12/04	7.2	141.08	33.20	50
1941/07/15	6.1	138.20	36.65	5	1973/06/17	7.4	145.95	42.97	40
1941/11/19	7.2	132.14	32.12	33	1973/06/17	5.7	145.47	42.87	40
1942/09/09	6.2	141.12	36.64	76	1973/06/24	7.1	146.75	42.95	30
1943/03/04	6.2	134.14	35.44	2	1974/05/09	6.9	138.80	34.57	10
1943/03/05	6.2	134.22	35.45	2	1974/11/09	6.3	141.78	42.47	130
1943/09/10	7.2	134.19	35.47	0	1975/01/23	6.1	131.13	33.00	0
1944/12/07	7.9	136.18	33.57	40	1978/01/14	7.0	139.25	34.77	0
1944/12/07	5.9	137.46	34.07	42	1978/02/20	6.7	142.20	38.75	50
1945/01/13	6.8	137.13	34.70	10	1978/06/12	7.4	142.17	38.15	40
1945/02/10	7.1	142.07	41.00	20	1980/06/29	6.7	139.23	34.92	10
1946/12/21	8.0	135.85	32.93	24	1981/01/23	6.9	142.20	42.42	130
1947/09/27	-	124.17	24.33	0	1982/03/21	7.1	142.60	42.07	40
1948/06/28	7.1	136.30	36.17	0	1983/05/26	7.7	139.08	40.36	14
1952/03/04	8.2	144.16	41.70	54	1983/10/03	6.2	139.52	34.00	15

1984/08/06	5.0	130.16	32.79	11	1997/03/05	4.9	139.16	34.96	3
1985/10/04	6.0	140.16	35.87	78	1997/03/07	5.0	139.15	34.97	1
1986/11/21	5.1	139.27	34.70	0	1997/03/16	5.9	137.53	34.92	39
1986/11/21	5.1	139.32	34.74	9	1997/03/26	6.6	130.36	31.97	12
1986/11/22	4.0	139.29	34.77	3	1997/04/03	5.7	130.32	31.97	15
1986/11/22	3.9	139.34	34.71	3	1997/04/05	5.2	130.41	31.97	12
1987/01/09	6.6	141.78	39.83	7	1997/05/13	6.4	130.31	31.94	9
1987/01/14	6.6	142.93	42.53	119	1997/06/25	6.6	131.67	34.44	8
1987/02/06	6.7	141.90	36.96	35	1998/08/12	5.0	137.63	36.23	3
1987/03/18	6.6	132.06	31.97	48	1998/09/03	6.2	140.90	39.80	8
1987/04/07	6.6	141.87	37.30	44	1999/02/26	5.3	139.84	39.15	21
1987/04/23	6.5	141.63	37.09	47	1999/03/14	5.1	139.14	34.23	9
1987/04/30	5.2	129.78	28.38	9	1999/08/21	5.6	135.47	34.03	66
1987/12/17	6.7	140.50	35.37	58	2000/03/30	4.5	140.82	42.52	5
1989/03/06	6.0	140.71	35.69	56	2000/03/30	4.2	140.83	42.70	4
1992/02/02	5.7	139.79	35.23	92	2000/04/01	4.9	140.83	42.50	7
1992/06/15	5.2	139.11	34.15	7	2000/06/03	6.1	140.75	35.69	48
1992/10/14	4.9	123.76	24.42	4	2000/06/07	6.2	135.57	36.82	21
1992/10/15	4.3	123.77	24.42	6	2000/06/08	5.0	130.76	32.69	10
1992/10/18	-	123.79	24.39	1	2000/06/29	5.4	139.16	34.23	12
1992/10/20	5.0	123.74	24.46	8	2000/07/01	6.5	139.20	34.19	16
1992/10/20	3.7	123.74	24.45	4	2000/07/09	6.1	139.23	34.21	15
1992/11/18	4.4	123.74	24.48	6	2000/07/15	6.3	139.25	34.42	10
1993/01/15	7.5	144.36	42.92	101	2000/07/20	5.1	139.18	34.29	7
1993/02/07	6.6	137.30	37.65	25	2000/07/20	5.1	139.23	34.20	12
1993/05/17	4.1	123.72	24.47	8	2000/07/20	5.2	139.25	34.20	15
1993/07/12	7.8	139.18	42.78	35	2000/07/20	4.4	139.24	34.22	15
1993/08/08	6.3	139.89	41.96	24	2000/07/21	6.4	141.12	36.53	49
1994/08/31	6.3	146.07	43.49	84	2000/07/23	5.3	139.26	34.26	11
1994/10/04	8.2	147.68	43.37	28	2000/07/24	5.7	139.23	34.18	12
1994/12/28	7.6	143.75	40.43	0	2000/07/24	4.9	139.20	34.36	6
1995/01/07	7.2	142.31	40.22	48	2000/07/27	5.8	139.30	34.19	13
1995/01/17	7.3	135.04	34.60	16	2000/07/28	5.0	139.21	34.21	16
1995/05/23	5.9	141.72	43.64	16	2000/07/28	5.0	139.32	34.15	14
1995/10/06	5.9	139.11	34.15	9	2000/07/30	6.0	139.41	34.03	11
1995/10/18	6.9	130.38	28.03	39	2000/07/30	6.5	139.41	33.97	17
1995/10/19	6.7	130.44	28.02	21	2000/07/30	5.9	139.41	34.02	17
1996/03/06	5.5	138.95	35.47	20	2000/08/03	5.2	139.29	34.22	16
1996/08/11	6.1	140.64	38.91	9	2000/08/03	5.0	139.24	34.21	13
1996/08/11	5.6	140.65	38.89	9	2000/08/03	5.0	139.25	34.19	15
1996/08/11	5.8	140.68	38.86	10	2000/08/03	5.4	139.26	34.23,	10
1996/09/11	6.4	141.22	35.64	52	2000/08/03	5.4	139.24	34.24	13
1996/10/19	6.9	132.01	31.80	34	2000/08/04	4.6	139.23	34.23	12
1996/12/03	6.7	131.68	31.77	38	2000/08/04	4.8	139.14	34.23	13
1996/12/21	5.6	139.86	36.09	53	2000/08/05	4.8	139.26	34.23	15
1997/02/20	5.9	142.88	41.76	49	2000/08/16	5.1	139.27	34.16	15
1997/03/03	5.5	139.16	34.96	0	2000/08/18	6.1	139.24	34.20	12

2000/08/18	5.1	139.18	34.29	7	2003/07/26	5.5	141.19	38.50	12
2000/08/29	5.1	139.23	34.38	10	2003/07/28	5.1	141.15	38.46	14
2000/09/11	5.4	139.22	34.51	11	2003/09/26	8.0	144.08	41.78	45
2000/10/02	5.3	129.34	29.39	22	2003/09/26	7.1	143.70	41.71	21
2000/10/02	5.9	129.46	29.41	25	2004/08/10	5.8	142.14	39.67	48
2000/10/02	4.6	129.44	29.45	21	2004/09/05	6.9	136.80	33.03	38
2000/10/06	7.3	133.35	35.27	9	2004/09/05	7.4	137.14	33.14	44
2000/10/06	4.1	133.33	35.32	6					
2000/10/08	5.2	133.31	35.37	8					
2000/10/31	5.7	136.33	34.30	39					
2000/11/14	4.9	123.76	24.48	8					
2001/01/02	4.5	138.60	37.25	12					
2001/01/04	5.3	138.77	36.95	11					
2001/02/13	4.5	139.16	34.33	7					
2001/03/24	6.7	132.70	34.13	46					
2001/03/26	5.2	132.71	34.11	46					
2001/04/03	5.3	138.10	35.02	30					
2001/12/02	6.4	141.27	39.4	122					
2001/12/08	4.6	139.15	35.54	24					
2001/12/09	6.0	129.49	28.25	36					
2002/02/12	5.7	141.09	36.59	48					
2002/10/14	6.1	142.28	41.15	53					
2002/11/03	6.3	142.14	38.89	46					
2002/11/04	5.9	131.87	32.41	35					
2003/05/26	7.1	141.65	38.82	72					
2003/07/26	5.6	141.17	38.43	12					
2003/07/26	6.4	141.17	38.4	12					
2003/07/26	5.1	141.17	38.45	13					

日本最大震度地図(1586-2004):データベースの構築と適用例

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要旨

日本で観測された歴史震度と気象庁の震度記録を用いて，1586年から2004年9月までの最大震度を地図化した。気象庁震度で４以上を記録した全337イベントを用いた。大きな震度が記録された領域が，太平洋沿岸に見られ，これは繰り返し発生する巨大プレート間地震に対応する。また陸域に於いて，内陸活断層上の地震による，パッチ状の震度の大きな領域が見られた。過去約400年間において、日本の領域の約90%で震度5弱以上を，30%で震度6弱以上を記録した。

キーワード: 気象庁震度，震度マップ

C-22

過去400年間の最大震度地図の作製

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1．はじめに

最近，地震調査研究推進本部を中心として，日本全国を概観した確率論的地震動予測地図の作成が進められている。一方，過去に記録された最大震度を調べることは，実際の震度再現値を求めることを可能にし，これを確率論的地震動予測地図と比較することには意義がある。歴史地震を用いた加速度予測の研究には，例えば川角マップなどがある。本研究は，最も直接的な方法として被害から求められた，或いは観測された震度をマッピングすることで，確率的地震動予測地図と比較可能な震度分布図を作製することを目的とする。

2．用いた震度記録とマッピング方法

1586年から2004年9月までの337イベントについて，その震度記録を用いた。1926 年以降，気象庁により震度が決定されているものは，その震度を用いた。但し，最大震度5以上を記録した地震に関して，震度4以上の地域のみを選んだ。1925 年以前に関しては，日本被害地震総覧（宇佐美著）を元に，震度分布が明らかな 1586 年以降の記録を用いた。用いたイベントの数は，1586 年－1925 年，1926 年－2004 年 9 月の期間で，それぞれ 80 個，257 個である。但し，イベントは全て地震とは限らず，火山性の場合も含まれる。現行震度で統一表示するために，歴史地震に関しては宇津の記載に従う。また気象庁の以前の震度について，5及び6に対して，それぞれ5弱及び6弱と過小評価した。

震度を記録した地点以外での震度は，周囲5観測点以上での計測震度と，その観測点までの距離を用いた線形補間により求めた。それぞれのイベントに対して，グリッド間隔 2^{-4} 度の震度分布図を作成した。

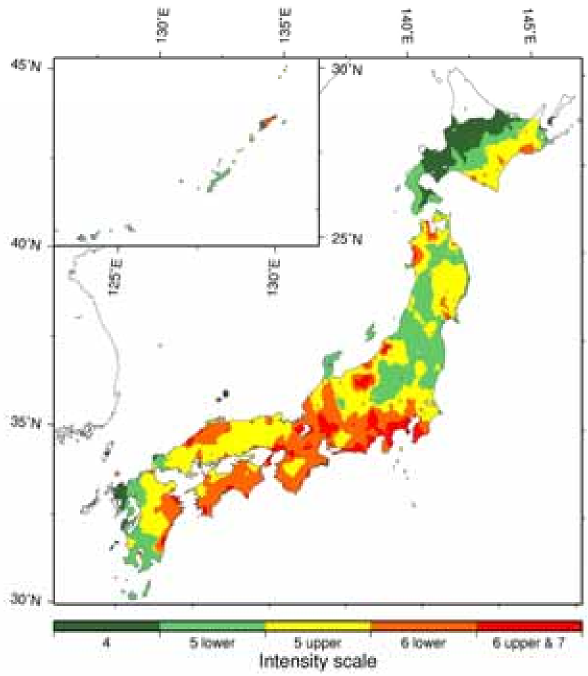
3．最大震度図

上記の方法で構築されるイベント毎の震度分布のデータベースは，任意の時空間に対して震度を与えることが出来るため，これを用いることで様々な解析が行える。

1586 年以降，最大震度が 4 以上を記録したと考えられる地域について，その最大震度を得た（図参照）。これは再現期間約 400 年に相当する最大震度図である。日本の陸領域の約 90%で震度5弱以上を，約 30%で震度6弱以上を記録した。

プレートの沈み込み帯で発生する地震のみを用いた震度地図では，太平洋側で大きな震度が観測された。例えば九州・北海道では海溝に沿って，震度の大きな帯状の分布が見られ，先に公表された確率論的地震動予測地図（再現期間500年）とよく似ている。また内陸地震を用いると，新潟から近畿にかけての内陸部や日本海側に，大きな震度の領域が顕著に点在する。

1901 年－2000 年のイベントを用いた最大震度地図では，このようなパターンは見出せず，100 年間では地震活動の歴史を示すには十分ではない。



図：1586 年—2004 年 9 月の最大震度地図