A Brief Study of Largest Earthquake Magnitudes in the Northwest Pacific Region

Tuncel M. Yegulalp

Data sources

The recent publication by USGS (Rhea, et al., 2011)[1] displays the seismic data observed and catalogued from 1900 -2007. It covers Japan and vicinity, Kuril-Kamchatka arc and vicinity and Aleutian Arc and vicinity in three detailed maps. Because the event magnitudes were graphically presented, it was not feasible to extract numeric data from these maps for statistical analysis. Instead, USGS databases were used. Maps were useful in delineating the relevant sections belonging to these regions.

Data was downloaded from USGS databases:
(http://earthquake.usgs.gov/earthquakes/eqarchives/epic/)

1. USGS/NEIC (PDE) 1973 - 2011 08 07
2. Significant Worldwide Earthquakes (2150 B.C. - 1994 A.D.)

Data Selection

Annual maximum magnitudes are selected from the combined databases within the specified areas. These areas and the rectangular segments used in retrieving the seismic data are shown in Figures 1,2,3,4,5,and 6.

Tables 1,2, and 3 list the maximum magnitudes for each region based on the two databases available online from USGS. Table 4 lists the largest earthquakes within the region covering all three areas specified above.

[1] Rhea, S., Tarr, A.C., Hayes, G., Villaseñor, A., Furlong, K.P., and Benz, H., 2010, Seismicity of the Earth 1900–2007, Aleutian arc and vicinity: U.S. Geological Survey Open-File Report 2010–1083-B, 1 map sheet, scale 1:5,000,000.

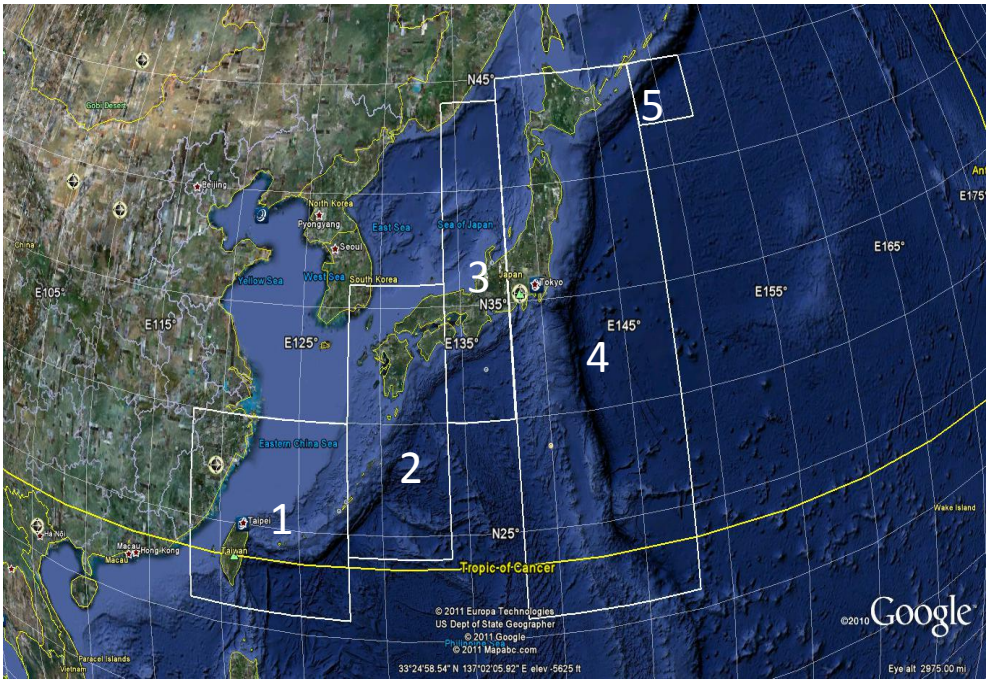

Figure 1 Five rectangular areas for selecting the data for Japan region

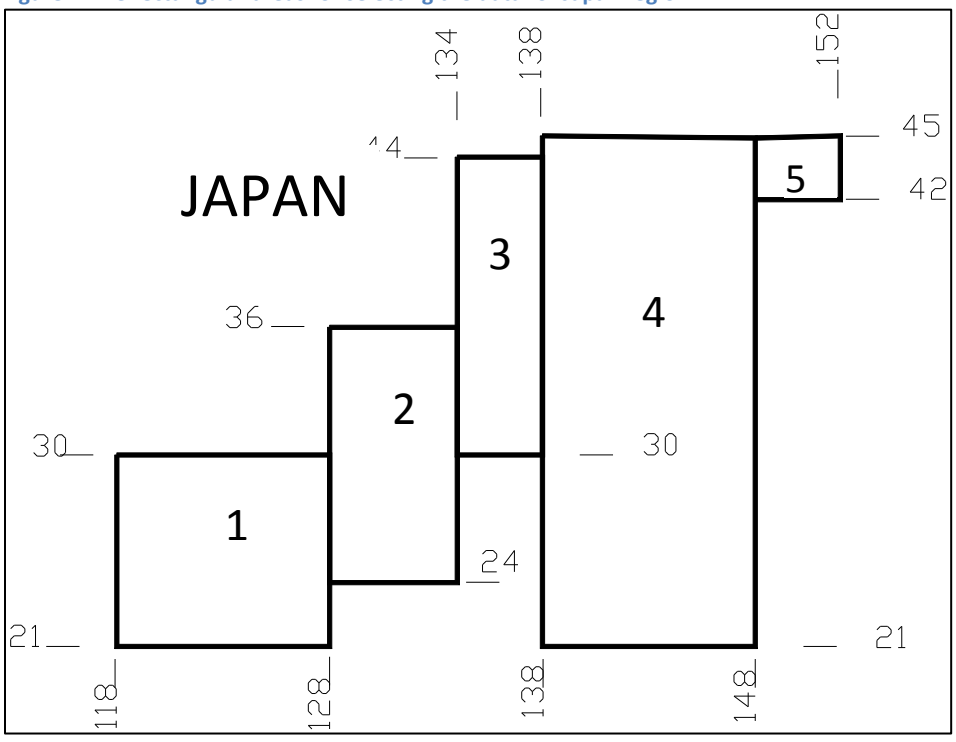

Figure 2 Coordinates of five rectangular areas used for selecting data for Japan

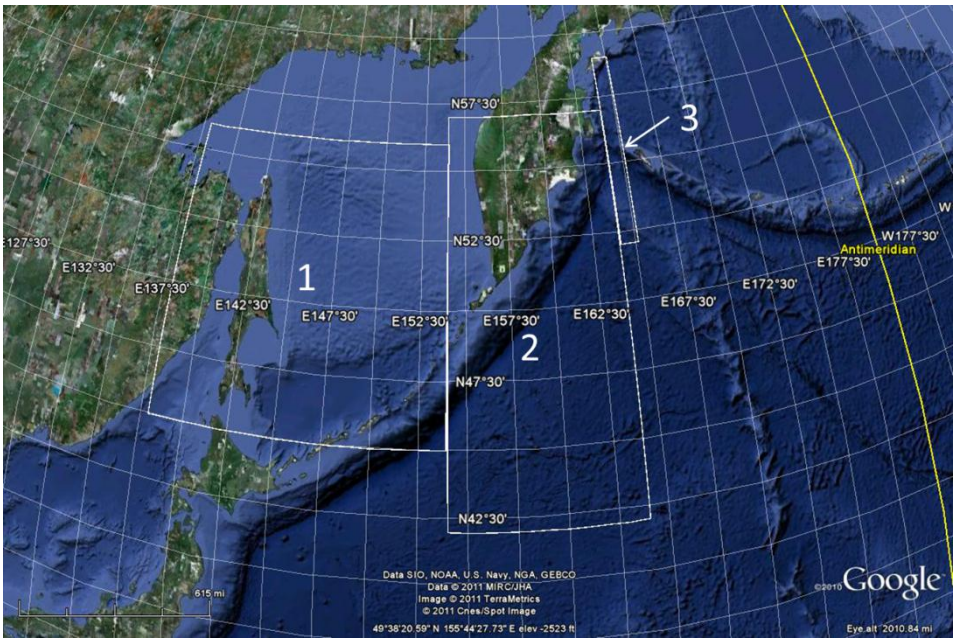

Figure 3 Three rectangular sections used for selecting data for Kuril-Kamchatka region

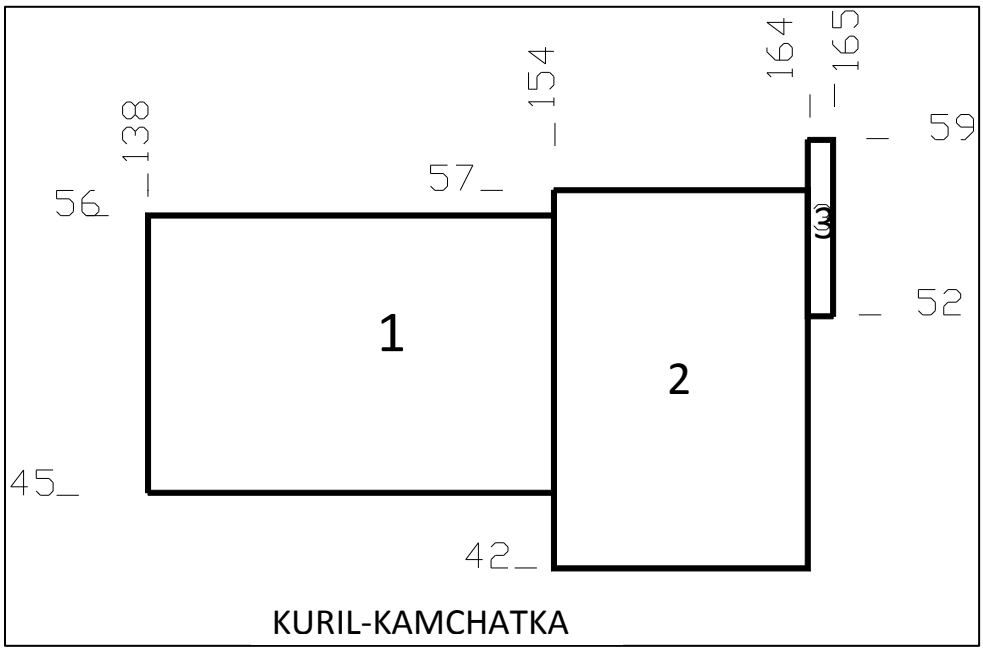

Figure 4 Coordinates for rectangular areas used for selecting data for Kuril-Kamchatka region

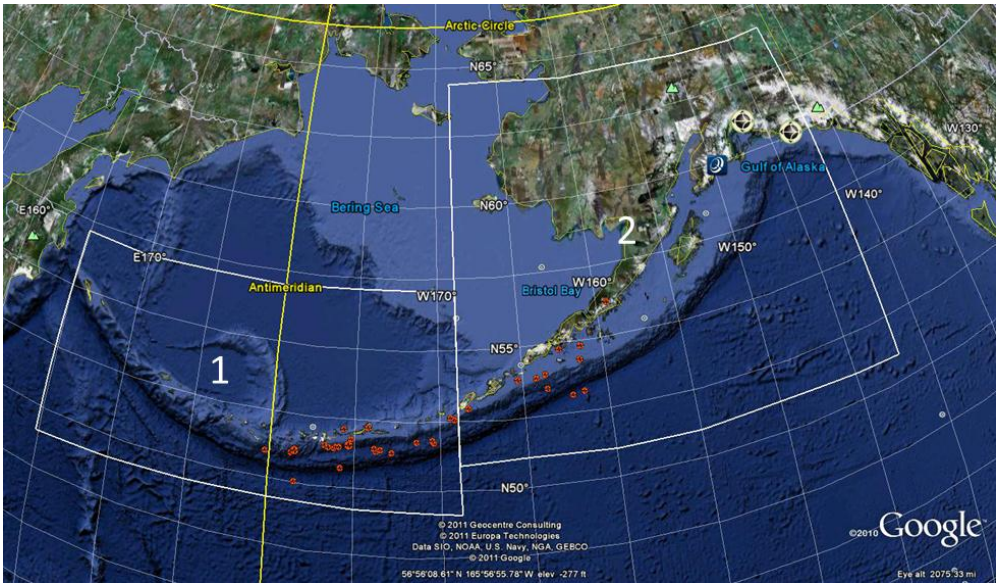

Figure 5 Two rectangular areas used for selecting data for Aleutian region

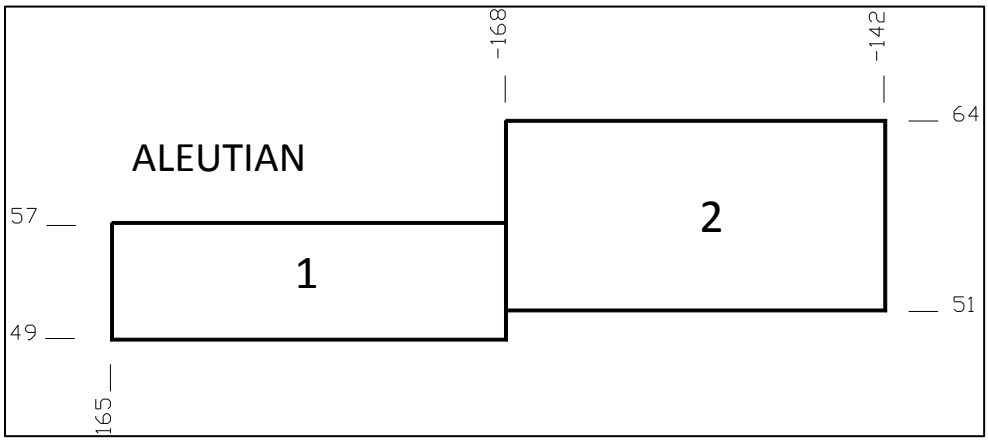

Figure 6 Coordinates for Two rectangular areas used for selecting data for Aleutian region

Data used in analysis

Table 1 Data used for analysis of Japan earthquakes (1900-2010)

Year	Month	Day	Time(hhmmss.mm)UTC	Latitude	Longitude	Magnitude	Depth	Catalog
1900	12	25	509	43	146	7.9	40	NOAA
1901	8	9	1833	40	144	8.2	60	NOAA
1904	8	24	2059	30	130	7.9	25	NOAA
1905	6	2	539	34	132	7.9	100	NOAA
1906	1	21	1349	34	138	8.3	340	NOAA

1908	11	6	712	45	150	7.6	60	NOAA
1909	3	13	1429	31.5	142.5	8.3	80	NOAA
1910	4	12	22	25.5	122.5	8.3	200	NOAA
1910	5	22	625	42	145	7.5	60	NOAA
1911	6	15		28	131	8.7	160	NOAA
1914	11	24	1153	22	143	8.7	110	NOAA
1915	11	1	723	39	142.5	7.8	60	NOAA
1916	2	1	736	29.5	131.5	8	60	NOAA
1917	7	4	38	25	123	7.7	60	NOAA
1918	11	8	438	44.5	151.5	7.9	25	NOAA
1919	5	3	52	40.5	145.5	7.6	60	NOAA
1920	6	5	421	23.5	122	8.3	10	NOAA
1922	9	1	1916	24.5	122	7.6	60	NOAA
1923	9	1	259	35.3	139.5	8.3	25	NOAA
1925	5	23	210	35.7	135	6.8		NOAA
1926	6	29	1427	27	127	7.5	130	NOAA
1927	3	7	928	35.7	135	7.9	10	NOAA
1930	11	25	1903	35	139	7.1		NOAA
1931	3	9	348	40.5	142.5	7.7	60	NOAA
1933	3	2	1730	39.2	144.5	8.8	25	NOAA
1934	7	17		24.6	120.7	6.3		NOAA
1935	9	11	1404	43	146.5	7.6	55	NOAA
1936	8	22	651	22.3	120.8	7.3		NOAA
1937	2	21	702	44.5	149.4	7.6	45	NOAA
1938	6	10	953	25.5	125	7.7	60	NOAA
1939	5	1	558	40	139.8	7		NOAA
1940	8	1	1508	44.3	139.5	7.7	40	NOAA
1941	11	18	1646	32	132	7.9	25	NOAA
1943	9	10	837	35.5	134.2	7.4	10	NOAA
1944	12	7	436	33.7	136	8.3	25	NOAA
1945	1	12	1838	34.7	137	7.1		NOAA
1946	12	20	1919	33	135.6	8.3	30	NOAA
1948	6	28	713	36.1	136.2	7.3	20	NOAA
1951	11	24	1850	23	122.5	7.3		NOAA
1952	3	4	603	42.5	143	8.6	25	NOAA
1953	11	25	1748	33.9	141.5	8.3	40	NOAA
1957	2	23	2026	23	122	7.1	69	NOAA
1958	11	6	2258	44.3	148.5	8.7	32	NOAA
1959	4	26	2040	24.9	122.8	7.7	113	NOAA
1961	8	19	533	36	136.7	7.3		NOAA
1962	4	30	226	38.7	141.1	6.4	100	NOAA

1963	10	13	517	44.8	149.5	8.3	47	NOAA
1964	6	23	126	43.3	146.1	7.6	77	NOAA
1966	3	12	1631	24.2	122.6	8	48	NOAA
1967	10	25	59	24.5	122.2	7	63	NOAA
1968	5	16	48	40.9	143.4	8.1	9	NOAA
1969	8	11	2127	43.5	147.4	8.2	28	NOAA
1972	1	25	341	23.1	122.1	7.7	34	NOAA
1973	6	17	355	43.2	145.7	7.7	48	NOAA
1974	5	8	2333	34.6	138.8	7	2	NOAA
1975	6	10	134714.5	43.024	147.734	7	15	PDE
1976	1	21	100524.1	44.915	149.123	7	41	PDE
1977	12	21	10032.8	25.51	143.112	6.9	33	PDE
1978	7	24	2354	22.1	121.4	8	18	NOAA
1979	2	20	63232.2	40.232	143.703	6.7	10	PDE
1980	2	23	55103.2	43.53	146.753	7.1	44	PDE
1981	1	18	181724.4	38.64	142.75	6.9	33	PDE
1982	6	30	15734.15	44.679	151.143	7.1	33	PDE
1983	5	26	3	40.6	139.1	7.8	24	NOAA
1984	3	24	94402.6	44.117	148.192	7	44	PDE
1985	8	12	34918.09	37.771	141.773	6.3	51	PDE
1986	11	14	212010.55	23.901	121.574	7.8	33	PDE
1987	1	9	61444.87	39.895	141.677	6.8	67	PDE
1988	1	2	124202.52	43.295	142.419	6.4	177	PDE
1989	11	1	1825	39.9	142.8	7.5	29	NOAA
1990	12	13	30148.05	23.916	121.636	6.7	12	PDE
1991	3	26	35823.26	21.704	121.789	6.5	17	PDE
1992	7	18	83658.7	39.419	143.33	6.9	28	PDE
1993	7	12	1317	42.9	139.2	7.7	17	NOAA
1994	10	4	1323	43.8	147.3	8.3	14	NOAA
1995	12	3	180108.99	44.663	149.3	7.9	33	PDE
1996	9	5	234206.15	21.898	121.498	6.8	20	PDE
1997	1	17	155313.43	28.814	129.953	6.3	33	PDE
1998	5	3	233021.91	22.306	125.308	7.5	33	PDE
1999	9	20	174718.49	23.772	120.982	7.7	33	PDE
2000	3	28	110022.51	22.338	143.73	7.6	126	PDE
2001	12	18	40258.28	23.954	122.734	6.8	14	PDE
2002	3	31	65250.49	24.279	122.179	7.1	32	PDE
2003	9	25	195006.36	41.815	143.91	8.3	27	PDE
2004	9	5	145718.61	33.184	137.071	7.4	10	PDE
2005	8	16	24628.4	38.276	142.039	7.2	36	PDE
2006	12	26	122621.14	21.799	120.547	7.1	10	PDE

2007	9	28	133857.88	22.013	142.668	7.5	260	PDE
2008	7	19	23928.7	37.552	142.214	7	22	PDE
2009	8	9	105555.11	33.167	137.944	7.1	292	PDE
2010	12	21	171940.66	26.901	143.698	7.4	14	PDE-W

Table 2 Data used for analysis of earthquakes in Kuril-Kamchatka region (1900-2010)

Year	Month	Day	Time(hhmmss.mm)UTC	Latitude	Longitude	Magnitude	Depth	Catalog
1901	4	5	2230	45	148	7.5	30	NOAA
1902	6	11	5	50	148	8	600	NOAA
1904	6	25	1445	52	159	8.3	25	NOAA
1905	9	15	602	53	164	7.8	60	NOAA
1907	5	25	1402	51.5	147	7.9	600	NOAA
1908	11	6	712	45	150	7.6	60	NOAA
1911	5	4	2336	51	157	7.6	240	NOAA
1913	8	1	1710	47.5	155.5	7.7	60	NOAA
1915	5	1	5	48.4	155.5	8.3	30	NOAA
1916	10	31	1531	45.5	154	7.7	30	NOAA
1917	1	30	245	55.2	164.5	8.1	40	NOAA
1918	9	7	1716	45.5	151.5	8.3	25	NOAA
1922	10	24	2121	47	151.8	7.5	90	NOAA
1923	2	3	1601	53	161	8.5	40	NOAA
1924	6	30	1544	45.1	147.4	7.6	120	NOAA
1929	1	13		50.6	154.7	7.8	135	NOAA
1936	11	13	1231	56.2	163.3	7.3	20	NOAA
1943	11	28	1711	54.9	156.8	7.6	350	NOAA
1950	2	28	1020	46	144	7.9	340	NOAA
1952	11	4	1658	52.3	161	8.5	40	NOAA
1956	10	11	224	45.9	150.5	7.8	105	NOAA
1959	5	4	715	53.1	160.3	8	20	NOAA
1963	3	16	844	46.6	154.7	7.5	10	NOAA
1969	1	19	702	45	143.2	7.6	204	NOAA
1971	12	15	829	55.9	163.4	7.8	30	NOAA
1973	2	28	637	50.4	156.7	7.5	27	NOAA
1974	5	15	185955.9	50.05	156.113	6.5	56	PDE
1975	12	21	105417.7	51.94	151.577	6.4	554	PDE
1976	1	6	210819.3	51.601	159.329	6	33	PDE
1977	12	20	85038.2	48.59	153.015	5.8	140	PDE
1978	3	3	105319.8	55.098	164.757	6.2	33	PDE
1979	8	22	182855.6	52.274	157.329	6.5	134	PDE

1980	12	31	103211	46.06	151.453	6.5	33	PDE
1981	2	6	164707.4	48.3	146.354	6	479	PDE
1982	11	21	232711.54	55.4	163.176	6.2	35	PDE
1983	8	17	105554.13	55.867	161.287	7	62	PDE
1984	12	28	103753.76	56.194	163.46	7	33	PDE
1985	5	2	85516.31	48.871	156.329	6.4	43	PDE
1986	5	2	103002.85	55.172	163.843	6	14	PDE
1987	5	7	30549.17	46.736	139.232	6.6	430	PDE
1988	9	21	95853.57	46.187	152.205	5.9	51	PDE
1989	4	11	35636.91	49.488	159.185	6.6	16	PDE
1990	5	12	45008.71	49.037	141.847	7.2	605	PDE
1991	12	22	84313.41	45.533	151.021	7.6	24	PDE
1992	3	2	122939.59	52.915	159.886	6.9	38	PDE
1993	6	8	1304	51.2	157.8	7.5	71	NOAA
1994	10	16	51000.93	45.749	149.167	6.7	116	PDE
1995	5	27	130352.65	52.629	142.827	7.1	11	PDE
1996	2	7	213646.3	45.324	149.892	7.2	42	PDE
1997	12	5	112654.69	54.841	162.035	7.8	33	PDE
1998	6	1	53403.58	52.889	160.067	6.5	43	PDE
1999	3	8	122548.99	52.056	159.52	6.9	56	PDE
2000	8	4	211302.71	48.786	142.246	6.8	10	PDE
2001	10	8	181426.44	52.591	160.324	6.5	48	PDE
2002	11	17	45353.54	47.824	146.209	7.3	459	PDE
2003	6	16	220802.14	55.492	159.999	6.9	174	PDE
2004	6	10	151957.75	55.682	160.003	6.9	188	PDE
2005	10	15	100617.01	46.816	154.113	6.1	42	PDE
2006	11	15	111413.57	46.592	153.266	8.3	10	PDE
2007	1	13	42321.16	46.243	154.524	8.1	10	PDE
2008	7	5	21204.48	53.882	152.886	7.7	632	PDE
2009	1	15	174939.07	46.857	155.154	7.4	36	PDE
2010	7	30	35613.71	52.498	159.843	6.3	23	PDE-W

Table 3 Data used for analysis of earthquakes in Aleutian region

Year	Month	Day	Time(hhmmss.mm)UTC	Latitude	Longitude	Magnitude	Depth	Catalog
1900	10	9	1228	60	-142	8.3	60	NOAA
1901	12	13		52	-176	7.8		NOAA
1902	1	1	520	52.4	-167.5	7.8	60	NOAA
1903	6	2	1317	57	-156	8.3	100	NOAA
1904	8	27	2156	64	-151	8.3	25	NOAA

1905	2	14	846	53	-178	7.9	60	NOAA
1906	8	17	10	51	179	8.3	25	NOAA
1907	9	2	1601	52	173	7.7	25	NOAA
1912	11	7	740	57.5	-155	7.5	90	NOAA
1916	4	18	401	53.3	-170	7.5	170	NOAA
1917	5	31	847	54.5	-160	7.9	60	NOAA
1929	3	7	134	51	-170	8.6	50	NOAA
1936	6	30	1506	55	165	7.2	20	NOAA
1938	11	10	2018	55.5	-158	8.7	25	NOAA
1940	7	14	552	51.7	177.5	7.7	80	NOAA
1946	4	1	1229	52.8	-162.5	7.4	50	NOAA
1948	5	14	2231	54.5	-161	7.5	25	NOAA
1957	3	9	1422	51.3	-175.8	8.6	33	NOAA
1964	3	28	336	61.1	-147.6	8.5	23	NOAA
1965	2	4	501	51.3	178.6	8.2	36	NOAA
1973	11	6	182635.1	51.579	-175.247	6.3	41	PDE
1974	2	6	40407.2	53.799	-164.672	6.5	2	PDE
1975	2	2	84339.1	53.113	173.497	7.6	10	PDE
1976	4	20	75953.8	53.534	-165.465	5.5	46	PDE
1977	2	19	223404.1	53.566	170.032	6.7	33	PDE
1978	5	24	61655.4	51.232	-179.213	6.7	25	PDE
1979	2	13	53425.9	55.453	-157.162	6.8	33	PDE
1980	3	24	35951.3	52.969	-167.67	7.1	33	PDE
1981	1	30	85244.1	51.744	176.274	7.1	33	PDE
1982	1	25	52933.52	53.222	-165.719	6.5	60	PDE
1983	7	12	1510	61	-147.2	6.6	30	NOAA
1984	9	23	170636.37	53.577	-165.424	5.9	33	PDE
1985	10	9	93332.48	54.765	-159.613	6.6	30	PDE
1986	5	7	224710.87	51.52	-174.776	8	33	PDE
1987	11	30	192319.59	58.679	-142.786	7.9	10	PDE
1988	3	6	223538.14	56.953	-143.032	7.8	10	PDE
1989	9	4	131458.25	55.543	-156.835	6.9	11	PDE
1990	11	6	201429.74	53.452	169.871	7.1	24	PDE
1991	5	30	131741.97	54.567	-161.606	7	28	PDE
1992	8	7	181920.44	57.589	-142.846	6.9	13	PDE
1993	5	15	215225.34	51.374	-178.669	6.9	32	PDE
1994	4	5	93544.88	51.296	-178.152	6.2	19	PDE
1995	4	23	25555.11	51.334	179.714	6.5	16	PDE
1996	6	10	40335.48	51.564	-177.632	7.9	33	PDE
1997	3	26	20857.27	51.277	179.533	6.7	33	PDE
1998	8	20	150008.1	51.618	175.248	6.3	33	PDE

1999	12	6	231233.92	57.413	-154.489	7	66	PDE
2000	7	11	13228.52	57.369	-154.206	6.6	43	PDE
2001	1	10	160244.23	57.078	-153.211	7	33	PDE
2002	11	3	221241	63.517	-147.444	7.9	4	PDE
2003	11	17	64306.8	51.146	178.65	7.8	33	PDE
2004	9	19	202604.1	52.205	174.027	6.2	25	PDE
2005	6	14	171012.28	51.239	179.314	6.8	17	PDE
2006	7	8	204000.98	51.214	-179.312	6.6	22	PDE
2007	12	19	93027.93	51.36	-179.509	7.2	34	PDE
2008	4	16	55419.69	51.878	-179.165	6.6	13	PDE
2009	10	13	53723.69	52.754	-166.997	6.5	24	PDE
2010	7	18	55644.93	52.876	-169.848	6.6	14	PDE-W

Statistical analysis

Statistical analysis of the largest earthquake magnitudes in these three regions was done using the procedure described in (Yegulalp. Kuo, 1972)[2], and the latest version of the earthquake software developed in house by Yegulalp (2010). The extremal distribution used for modeling the largest earthquake magnitudes is:

$$\Phi(x) = e^{-\left(\frac{\omega - x}{\omega - \nu}\right)^{1/\lambda}}$$

Where :

$\Phi(x) = Prob.\{X \leq x\}$

$\omega = The\ upper\ bound$

$\nu = The\ characterostic\ largest\ value$

$\lambda = The\ shape\ parameter$

An additional analysis was made by combining the data from all three regions and selecting the largest magnitudes within the combined region.

[2] Yegulalp, T.M., and J.T. Juo, 1974, Statistical Prediction of the occurrence of maximum magnitude earthquakes, *Bull. Seis. Soc. of America, V. 64, No 2*, pp. 393-414.

Results

Table 4 lists the parameters extremal distributions for 3 regions and the combined region including all regions as a unit.

Table 4 Estimated parameters of extremal fitted distributions

	Parameters		
	ω	ν	λ
All Combined	8.9166	7.385	0.522
Aleutian	8.929	5.39	0.612
Japan	8.918	7.00	0.5168
Kuril_Kamchatka	8.405	5.366	0.933

Figures 4,5, 6 and 7show the plots of observed and fitted cumulative distributions .

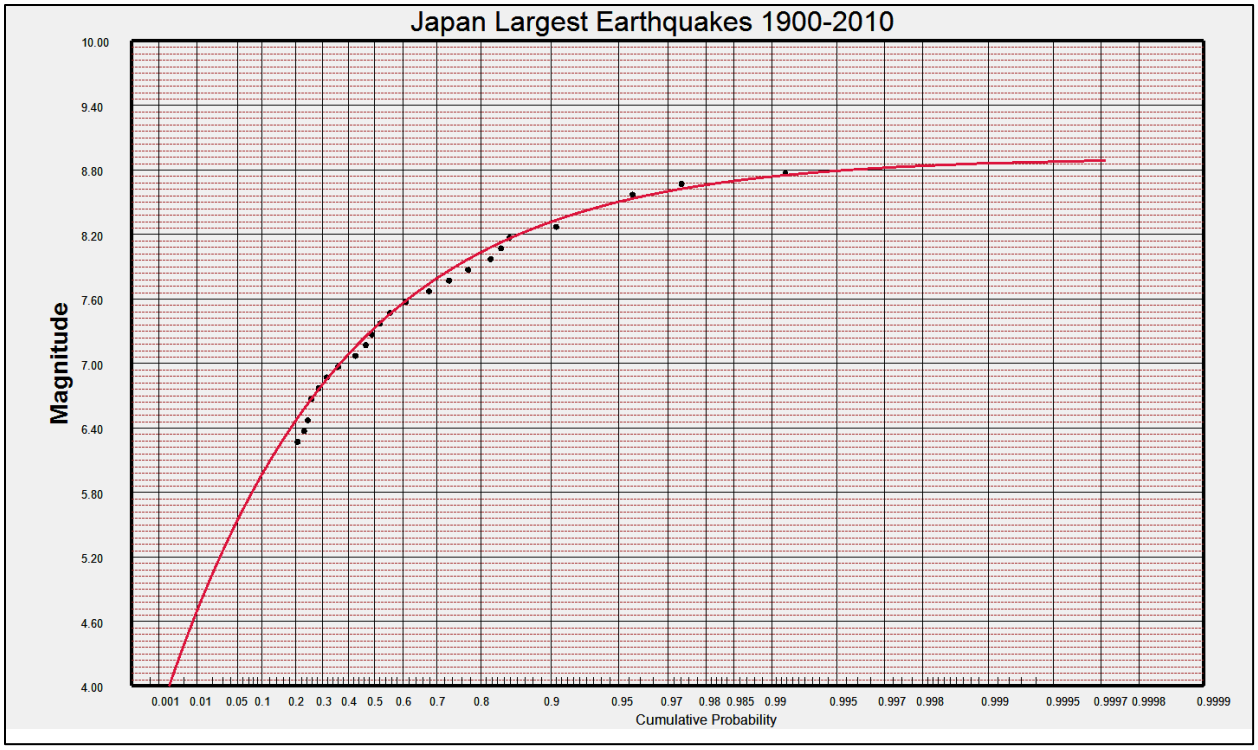

Figure 7 Observed and fitted cumulative distributions for Japan

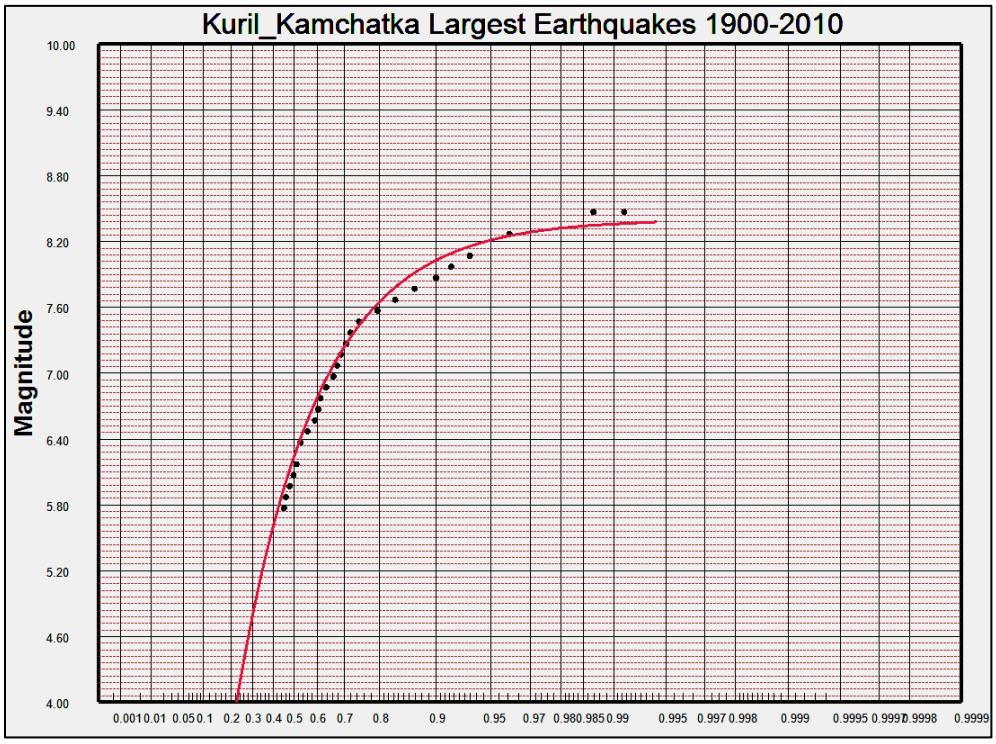

Figure 8 Observed and fitted cumulative distributions for Kuril- Kamchatka region

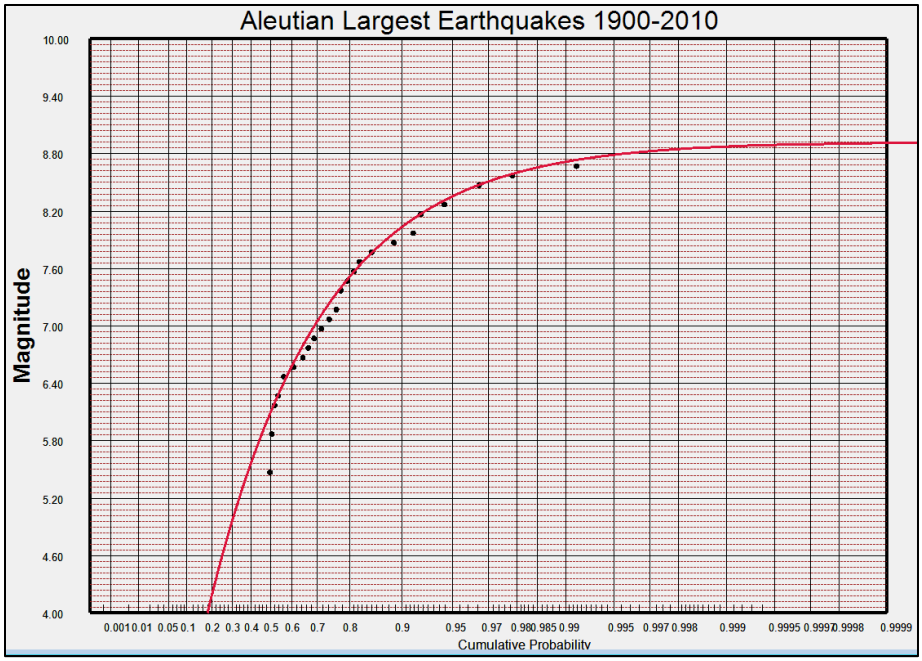

Figure 9 Observed and fitted cumulative distributions for Aleutian region

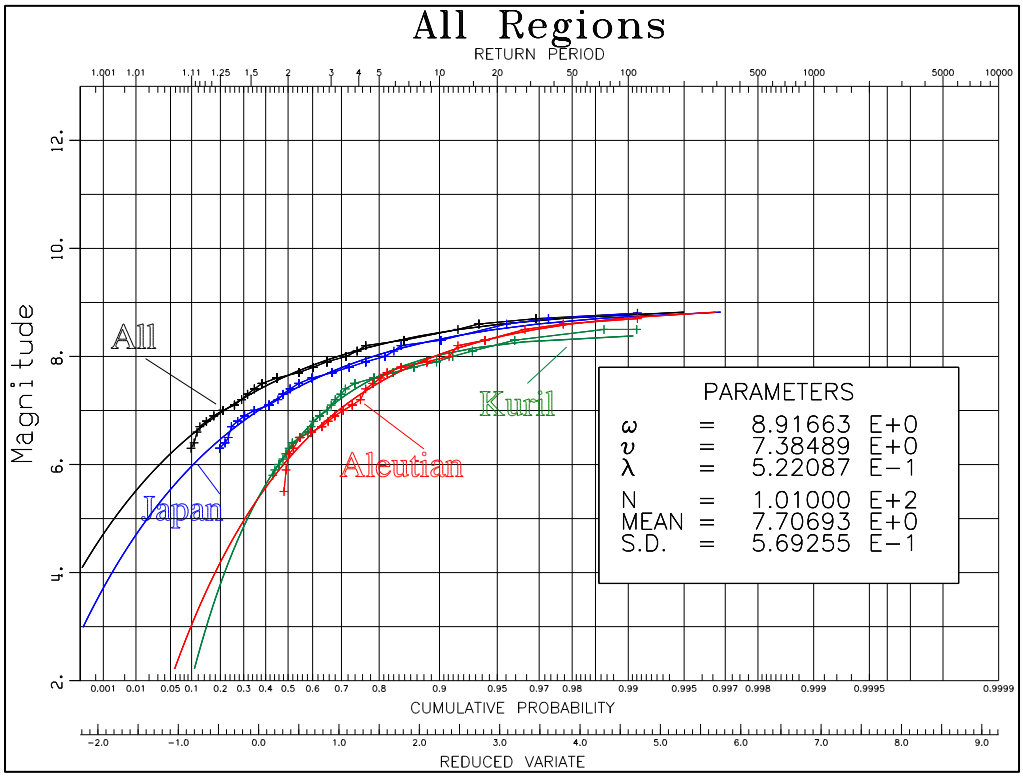

Figure 10 Observed and fitted distributions in all regions and the combined region

The return periods

The return period T(x) is defined by:

$$T(x) = \frac{1}{1 - \Phi(x)}$$

Table 5 shows the return periods (in years) for three regions and the combined region..

Table 5

	Parameters			Return Periods (Years)						
	ω	ν	λ	8.1	8.3	8.5	8.6	8.7	8.8	
All Combined	8.9166	7.385	0.522	4	6	13	21	43	139	
Aleutian	8.929	5.39	0.612	11	17	32	49	88	224	
Japan	8.918	7	0.5168	6	9	20	33	68	220	
Kuril_Kamchatka	8.405	5.366	0.933	12	37					