Scientometric mapping of Tsunami publications: a citation based study

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ABSTRACT

The objective of the study was to perform a scientometric analysis of all Tsunami related publications as per the Scopus [TM] database during 1997-2008. A total of 4338 publications and 21107 citations to these papers were received. The parameters studied include growth of publication, country-wise distribution of publications, activity index of countries, most-frequently cited publications, authorship pattern, co-authorship index, and distribution of keywords. United States of America, Japan, United Kingdom, India and Australia produced 54.20% of the total output. A spurt in number of publications was observed after the Indonesia's tsunami occurred on 26 December 2004.

Keywords: Tsunami; Citation analysis; Highly Cited Authors; Bibliometrics; Scientometrics,; Publication Productivity; Author Productivity; Institutional Productivity

INTRODUCTION

A tsunami is a series of water waves (called a tsunami wave train (Fradin and Brindell 2008)) that is caused when a large volume of a body of water, such as an ocean, is rapidly displaced. It is a Japanese word with the English translation "harbor wave". Earthquakes, volcanic eruptions and other underwater explosions (detonations of nuclear devices at sea), landslides and other mass movements, bolide impacts, and other disturbances above or below water all have the potential to generate a tsunami. Due to the immense volumes of water and energy involved, the effects of tsunamis can be devastating (National Geophysical Data Center (NGDC) 2009).

Tsunamis are among the most terrifying natural hazards known to man and have been responsible for tremendous loss of life and property throughout history. Because of their destructiveness, tsunamis have notable impact on the human, social and economic sectors of our societies. In the Pacific Ocean, where the majority of these waves have been generated, the historical record shows wide scale destruction. In Japan, which has one of the most populated coastal regions in the world and a long history of earthquake activity, tsunami has destroyed large coastal populations. There is also a history of tsunami destruction in Alaska, in the Hawaiian Islands in South America, Japan and elsewhere in the Pacific (Department of Ocean Development 2005).

Scientometrics is a discipline which analyses scientific publications and citations appended to the papers to gain an understanding of the structure of science, growth of science at global level, performance of a country in a particular domain, performance of institutions, departments/divisions, and scientific eminence of an individual scientist. It also helps in knowing the information seeking behaviour of scientists and engineers by way of identifying where they publish and what they cite (Sagar et al. 2009ab).

Many scientometric studies have been presented in the literature to focus on the performance of science in various domains (Czerwon 1990; Hall 1992; Kademani and Kumar 2002a; 2002b; Kademani et al. 2005a; 2005b; 2006a; 2006b; 2006c; 2006d; 2007a; 2007b; Lawson et al. 1980; Mavguin 1991; Sagar et al. 2007; 2009c; Verma et al. 1982). Publication and citation counting techniques have been used in the assessment of scientific activity for at least fifty years. During this activity the main thrust of interest seems to flow along two connected but parallel paths: the bibliometric path of publication and citation counts as tools, and an evaluative path using the same tools to illuminate the mosaic of scientific activity (Narin 1976).

OBJECTIVES

The main objective of the study is to present the growth of Tsunami literature published during 1997-2008 as per the *Scopus* [TM] database and make the quantitative and qualitative assessment by way of analyzing various features of research output such as growth of publications and citations, authorship pattern citations, highly cited scientists, and highly cited Tsunami publications and keywords.

MATERIALS AND METHODS

Data was collected from the *Scopus* [TM] database (1997-2008). The *Scopus* database was launched in autumn 2004 by Elsevier and is the largest abstract and citation database of peer-reviewed literature covering all subjects. The search string 'Tsunami' in the Title, Abstract and Keyword field was used to extract publications related to Tsunami. A total of 4338 publications and 21107 citations to these papers were received. The data was downloaded and analysed by using the spread sheet application as per objectives of the study.

RESULTS AND DISCUSSION

Year-wise Growth of Publications and Citations

A total of 4338 Tsunami publications were published during 1997-2008 which received 21107 citations. The highest number of publications (1053) were published in 2005 and these papers have received the highest citations (4022). The average number of publications published per year was 361.50 and the average number of citations per paper was 4.87. Table 1 and Figure 1 present the year-wise growth of publications and their citations. It was observed that more number of papers in a particular year received more number of citations and this indicates that quality and quantity of research always go hand

in hand. A spurt of publications was observed in 2005 as a result of Indonesia's Tsunami occurred on 26 December 2004. Figure 2 presents the year-wise growth rate of Tsunami publications.

Table 1: Growth of Publications and Citations of Tsunami Research during 1997-2008

Publication Year	No. of Publications	% of Publications	Growth Rate in %	Number of Citations	% of Citations
1997	88	2.03	-	1474	6.98
1998	96	2.21	9.09	1286	6.09
1999	107	2.47	11.46	1745	8.27
2000	142	3.27	32.71	1649	7.81
2001	136	3.14	-4.23	1333	6.32
2002	127	2.93	-6.62	1559	7.39
2003	201	4.63	58.27	1744	8.26
2004	177	4.08	-11.94	1457	6.90
2005	1053	24.27	494.92	4022	19.06
2006	790	18.21	-24.98	2764	13.10
2007	715	16.48	-9.49	1520	7.20
2008	706	16.27	-1.26	554	2.62
Total	4338	100.00	-	21107	100.00

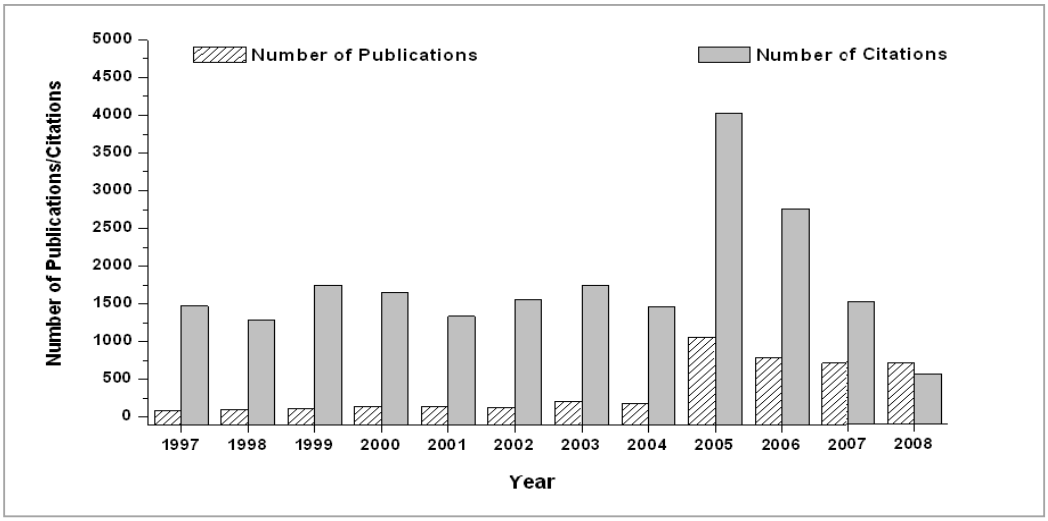

Figure 1: Year-wise Growth of Tsunami Publications and Citations

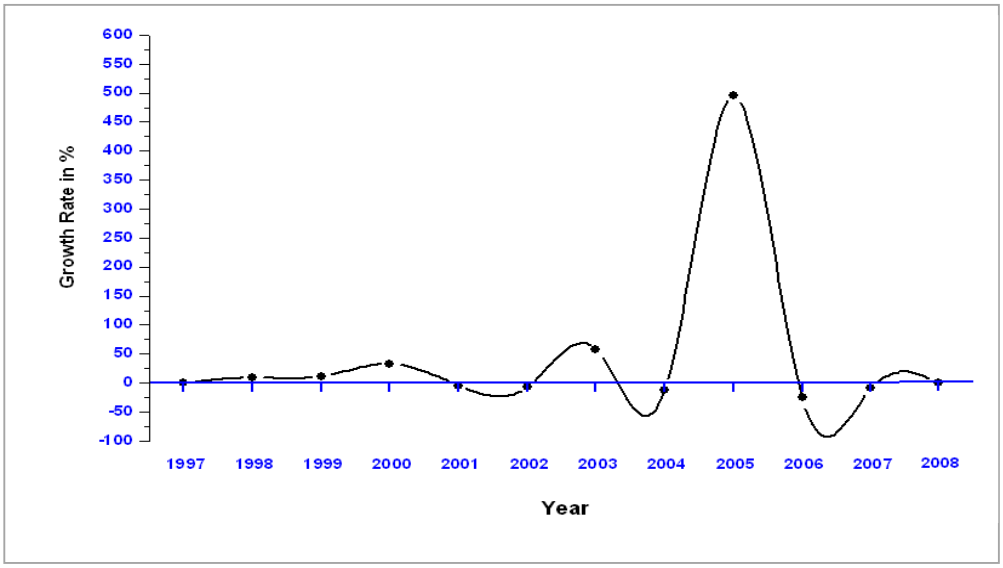

Figure 2: Growth Rate of Tsunami Publications during 1997-2008

Country-wise Distribution of Publications and Citations

In total, there were 100 countries involved in Tsunami related research for the publications and citations analysed. United States of America (USA) topped the list with 1081 (24.92%) publications which received 8534 (40.43%) citations, Japan with 427 (9.84%) publications which received 2668 (12.64%) citations, United Kingdom with 320 (7.38%) publications which received 2067 (9.79%) citations, India with 294 (6.78%) publications which received 857 (4.06%) citations and Australia with 229 (5.28%) publications which received 1173 (5.56%) citations. Table 2 presents the country-wise distribution of the publications and citations.

Table 3 presents the year-wise publication output of top ten countries. The Activity Index (AI) characterizes the relative research efforts of a country in a given subject, as defined by Karki, Garg and Sharma (2000) who studied the activity and growth of organic chemistry in India. The year-wise Activity Index of top ten countries is given in Figures 3a – 3j. Russian Federation had the highest activity Index (267.62) in 1998, Canada (225.08) in 2002, France (192.11) in 1998, Italy (182.55) in 1999, India (178.73) in 2005, Germany (174.89) in 2004, USA (161.38) in 2002, Japan (152.12) in 2000 and United Kingdom (152.12) in 2000.

Table 2: Country-wise Distribution of Tsunami Publications and Citations

Rank	Country	TP	% TP	TC	% TC	ACP
1	United States	1081	24.92	8534	40.43	7.89
2	Japan	427	9.84	2668	12.64	6.25
3	United Kingdom	320	7.38	2067	9.79	6.46
4	India	294	6.78	857	4.06	2.91
5	Australia	229	5.28	1173	5.56	5.12
6	Italy	198	4.56	1596	7.56	8.06
7	France	185	4.26	1218	5.77	6.58
8	Canada	174	4.01	1446	6.85	8.31
9	Germany	171	3.94	1194	5.66	6.98
10	Russian Federation	166	3.83	784	3.71	4.72
11	Thailand	114	2.63	508	2.41	4.46
12	China	86	1.98	240	1.14	2.79
12	New Zealand	86	1.98	755	3.58	8.78
13	Indonesia	80	1.84	606	2.87	7.58
14	Sri Lanka	76	1.75	271	1.28	3.57
15	Norway	70	1.61	677	3.21	9.67
16	Spain	64	1.48	487	2.31	7.61
17	Netherlands	62	1.43	382	1.81	6.16
18	Switzerland	55	1.27	365	1.73	6.64
19	Singapore	51	1.18	165	0.78	3.24
20	Greece	49	1.13	371	1.76	7.57
21	Turkey	48	1.11	256	1.21	5.33
22	South Korea	45	1.04	153	0.72	3.40
23	Portugal	39	0.90	382	1.81	9.79
24	Sweden	38	0.88	145	0.69	3.82
25	Malaysia	37	0.85	119	0.56	3.22
25	Mexico	37	0.85	227	1.08	6.14
25	Taiwan	37	0.85	103	0.49	2.78
26	Denmark	27	0.62	220	1.04	8.15
27	Belgium	21	0.48	275	1.30	13.10
27	Chile	21	0.48	210	0.99	10.00
28	Hong Kong	17	0.39	31	0.15	1.82
29	Finland	16	0.37	41	0.19	2.56
29	Israel	16	0.37	50	0.24	3.13
29	Poland	16	0.37	117	0.55	7.31
30	Austria	15	0.35	46	0.22	3.07
30	Ukraine	15	0.35	10	0.05	0.67
31	Brazil	13	0.30	65	0.31	5.00
31	England	13	0.30	16	0.08	1.23
32	Ireland	12	0.28	92	0.44	7.67
33	Egypt	11	0.25	35	0.17	3.18
33	South Africa	11	0.25	78	0.37	7.09

(TP=Total number of publications; TC=Total number of citations;
ACP=Average citations per publication)

Table 3: Year-wise Publications Productivity of Top Ten Countries during 1997-2008

Countries	Publication Year												Total
	97	98	99	00	01	02	03	04	05	06	07	08	
United States	22	30	29	38	41	49	81	54	156	181	183	217	1081
Japan	14	9	19	26	17	14	28	28	48	68	75	81	427
United Kingdom	5	10	9	16	10	7	11	15	67	60	66	44	320
India	1	-	-	-	-	-	1	1	94	81	61	55	294
Australia	4	5	4	3	5	-	12	11	36	43	52	54	229
Italy	5	5	9	11	8	5	13	16	28	33	30	35	198
France	5	8	7	9	7	5	9	5	30	34	29	37	185
Canada	5	2	6	4	5	11	12	5	26	33	37	28	174
Germany	1	5	3	3	3	3	9	14	34	30	31	35	171
Russian Federation	6	10	7	12	5	9	14	11	22	19	22	29	166
Other 90 countries	22	29	32	43	39	38	65	75	357	355	350	370	1775
Total	90	113	125	165	140	141	255	235	898	937	936	985	5020

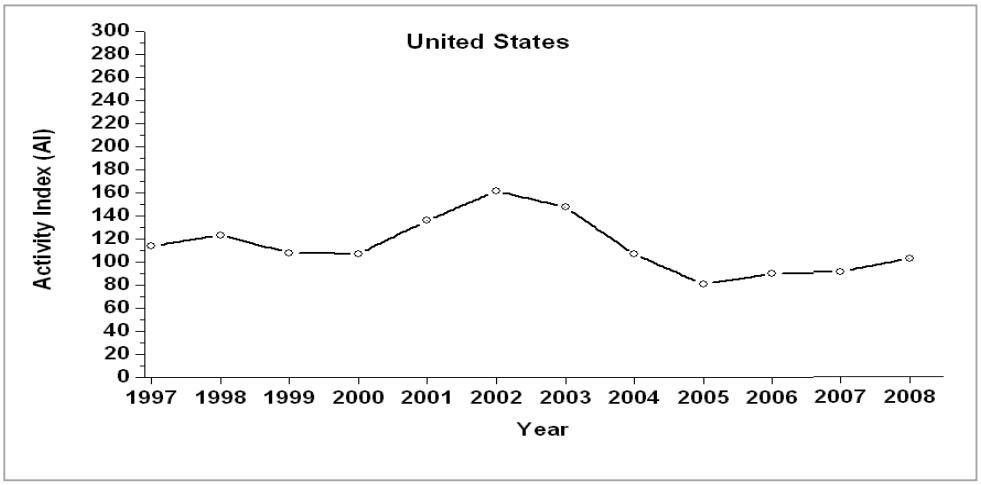

Figure 3a: Activity Index in Tsunami Publications of USA during 2000-2007

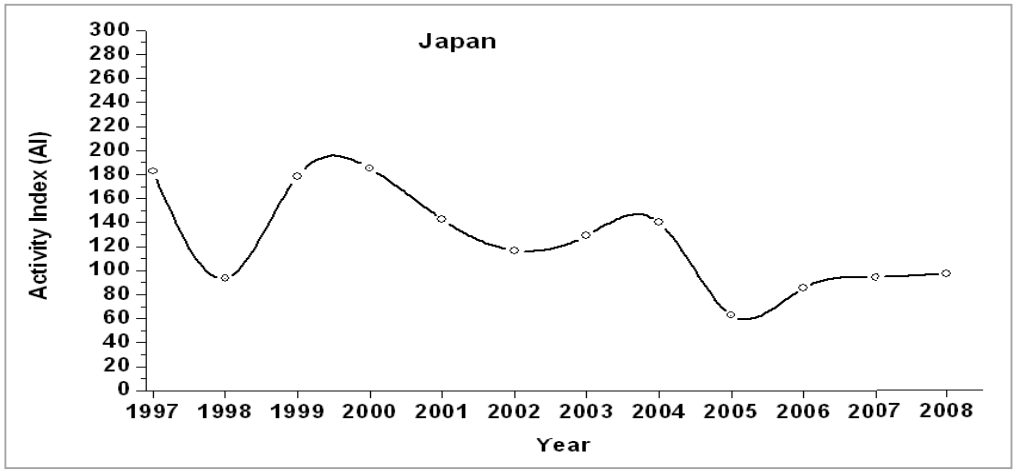

Figure 3b: Activity Index in Tsunami Publications of Japan during 2000-2007

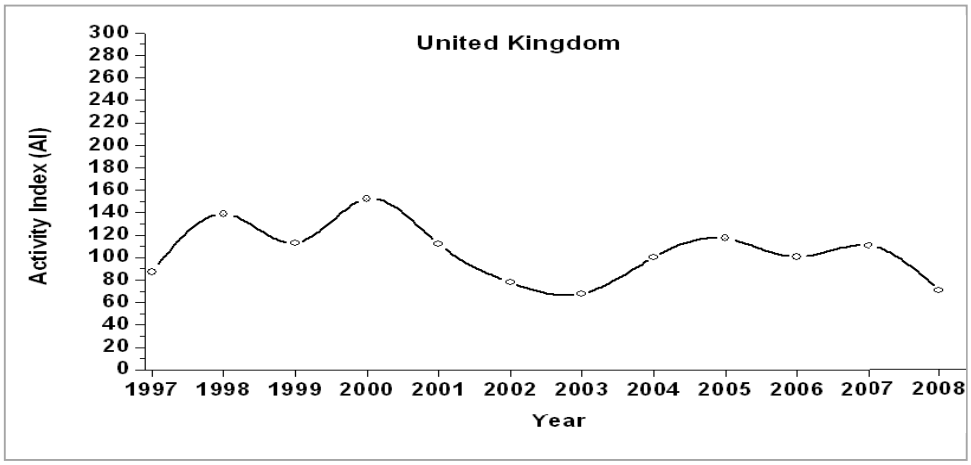

Figure 3c: Activity Index in Tsunami Publications of United Kingdom during 2000-2007

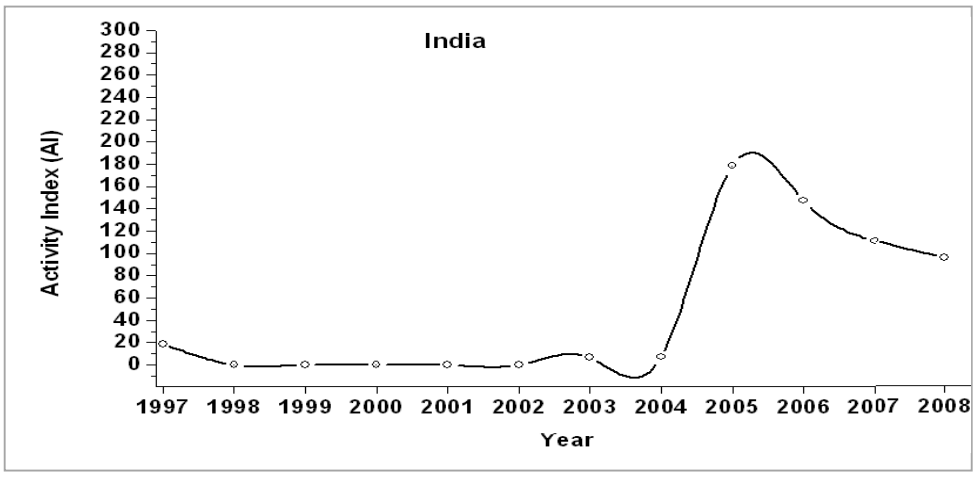

Figure 3d: Activity Index in Tsunami Publications of India during 2000-2007

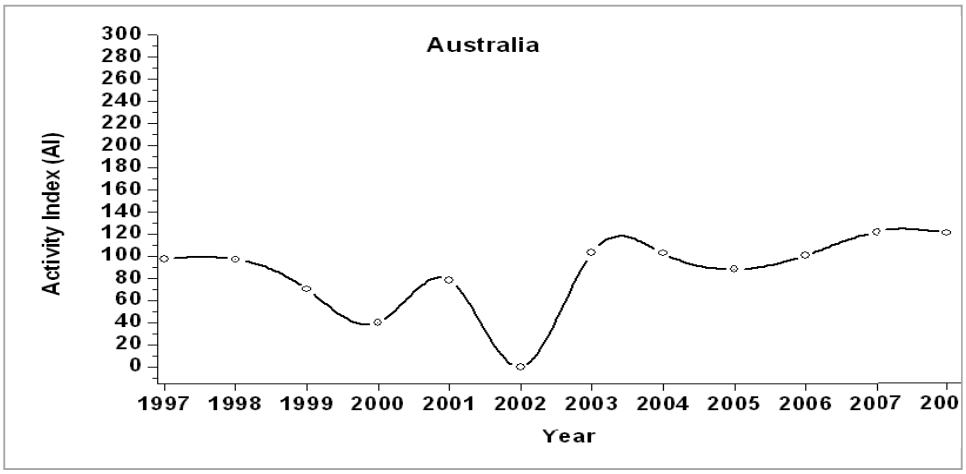

Figure 3e: Activity Index in Tsunami Publications of Australia during 2000-2007

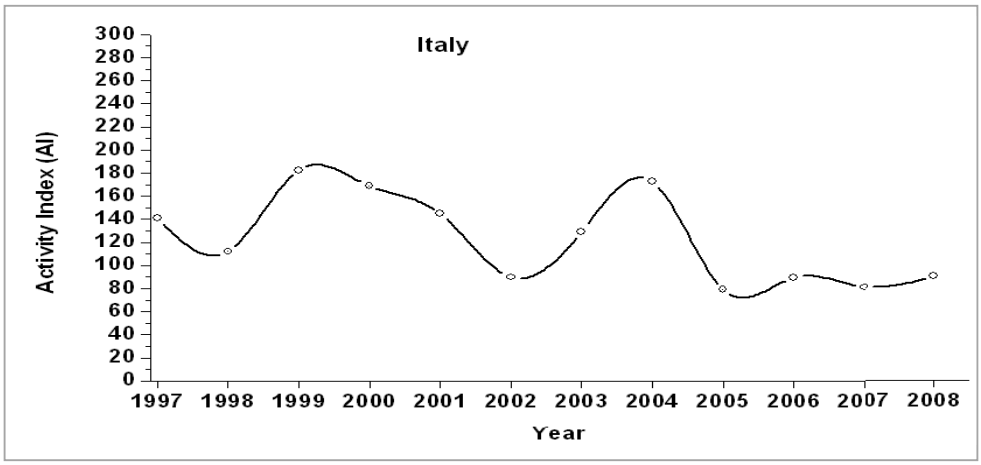

Figure 3f: Activity Index in Tsunami Publications of Italy during 2000-2007

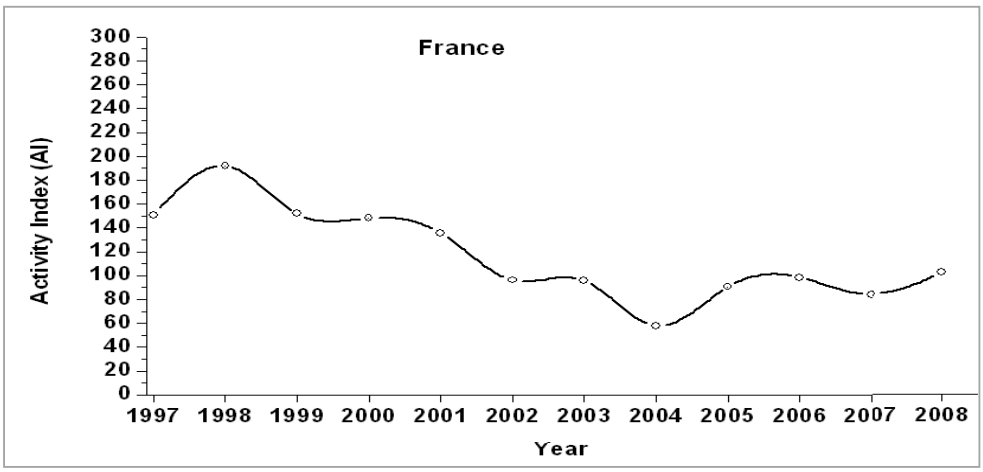

Figure 3g: Activity Index in Tsunami Publications of France during 2000-2007

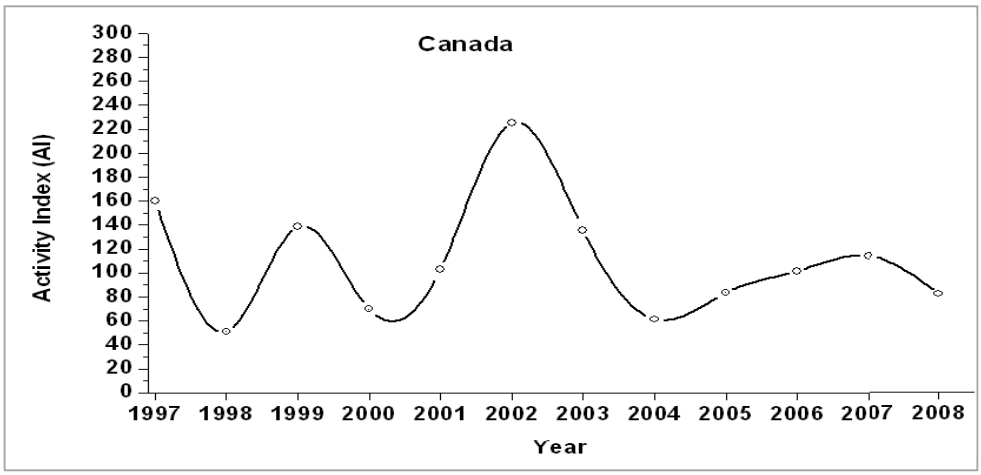

Figure 3h: Activity Index in Tsunami Publications of Canada during 2000-2007

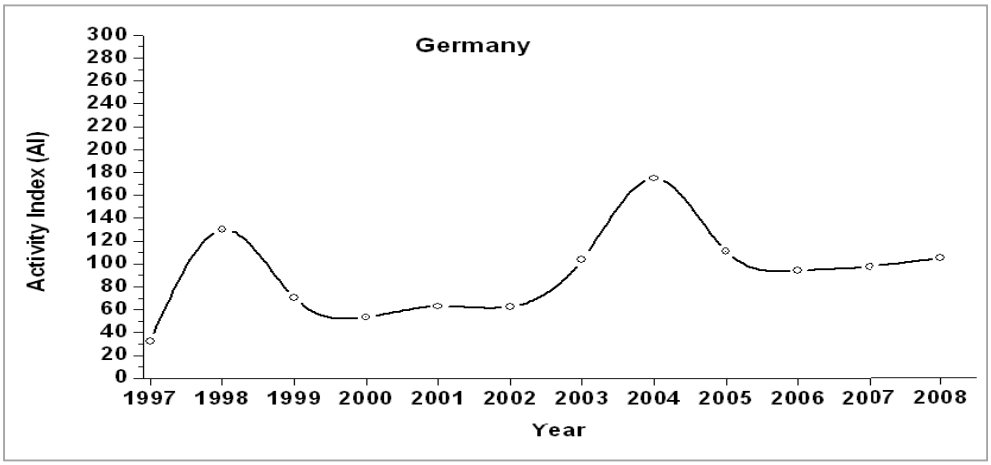

Figure 3i: Activity Index in Tsunami Publications of Germany during 2000-2007

Figure 3j: Activity Index in Tsunami Publications of Russian Federation during 2000-2007

Citations Vs Authorships

Jointly authored papers tend to be cited more than others. In fact, the more authors a paper has, the more likely it is to be cited. For the field of cancer research, Lawani (1980) has shown clearly that citation rate and quality of paper (as judged by a forum of peer review) both correlate positively with the number of authors per paper. Smart and Bayer (1986) stated that the acceptance rate of articles which are collaboratively authored tends to be higher than that for single authored papers, thereby suggesting a generally positive relationship between collaboration and quality. The analysis of ten year citation rates of 270 randomly selected articles in three applied fields likewise shows a similar relationship, with somewhat higher citation frequencies for multi-authored papers than for single authored ones. The relationship persists whether self-citations are included or excluded. However, those differences are not statistically significant for articles in clinical psychology or educational measurement. Only multi-authored articles in management science show a statistically significant higher citation rate.

The number of citations received in relation to authorship pattern is given in Table 4. Single-authored 1328 (30.61%) publications received 3559 (16.86%) citations and multi-authored 3010 (69.39%) publications received 17548 (83.14%) citations. A total of 5434 (25.75%) citations were for two authored (873) publications followed by three authored (695) publications with 3800 (18.00%) citations and four authored (461) publications with 2140 (10.14%) citations. There were 136 (3.14%) publications on Tsunami in the *Scopus*^{TM} database that are without any author affiliation.

Table 4: Authorship Trend in Tsunami Publications and Citations

Author (s) in by-line	No. of Publications	%. of Publications	No. of Citations	% of Citations
N/A	136	3.14	59	0.28
1	1328	30.61	3559	16.86
2	873	20.12	5435	25.75
3	695	16.02	3800	18.00
4	461	10.63	2140	10.14
5	301	6.94	1891	8.96
6	189	4.36	890	4.22
7	112	2.58	651	3.08
8	73	1.68	601	2.85
9	50	1.15	520	2.46
10	36	0.83	244	1.16
11	27	0.62	299	1.42
12	13	0.30	232	1.10
13	8	0.18	96	0.45
14	9	0.21	325	1.54
15	7	0.16	76	0.36
16	5	0.12	54	0.26
17	2	0.05	99	0.47
18	4	0.09	25	0.12
19	1	0.02	28	0.13
21	2	0.05	7	0.03
22	1	0.02	0	0.00
24	1	0.02	36	0.17
25	1	0.02	1	0.00
26	1	0.02	6	0.03
27	2	0.05	33	0.16
Total	4338	100.00	21107	100.00

(N/A= Author (s) not available in by-line)

Highly Cited Authors

Table 5 gives the highly cited authors in Tsunami publications. K. Satake obtained 868 citations for his 45 publications followed by P. Watts who received 514 citations for his 34 publications, S. N. Ward received 513 citations for his 12 publications, C. E. Synolakis received 479 citations for his 32 publications, H. Kanamori received 465 citations for his 11 publications, Y. Tanioka received 382 citations for his 27 publications, S. Tinti received 378 citations for his 36 publications, E. A. Okal received 355 citations for his 32 publications, S. L. Bilek received 345 citations for his 9 publications, A. B. Rabinovich received 336 citations for his 26 publications, L. R. Beuchat received 325 citations for his 10 publications, and T. Lay received 317 citations for his 6 publications.

Table 5: Highly Cited Authors in Tsunami Research as per *Scopus*^{TM} Database during 1997-2008

Author (s)	#Publications	#Citations	Author (s)	#Publications	#Citations
Satake, K.	45	868	Chague-Goff, C.	7	163
Watts, P.	34	514	Nanayama, F.	8	163
Ward, S.N.	12	513	Liu, P.L.-F.	10	162
Synolakis, C.E.	32	479	Kelletat, D.	16	161
Kanamori, H.	11	465	Taormina, P.J.	2	161
Tanioka, Y.	27	382	Bortolucci, E.	11	158
Tinti, S.	36	378	MacPhee, R.D.E.	1	156
Okal, E.A.	32	355	Dawson, S.	11	153
Bilek, S.L.	9	345	Titov, V.	8	150
Rabinovich, A.B.	26	336	Smith, D.E.	11	148
Beuchat, L.R.	10	325	Jaffe, B.E.	9	146
Lay, T.	6	317	Shigeno, K.	5	146
Titov, V.V.	18	269	Gelfenbaum, G.	13	145
Ekstrom, G.	5	267	McMurtry, G.M.	6	145
Ammon, C.J.	5	255	Baptista, M.A.	10	144
Mofjeld, H.O.	14	249	Hebert, H.	16	143
Clague, J.J.	13	248	Hyndman, R.D.	3	143
Butler, R.	3	246	Chlieh, M.	6	142
Beck, S.L.	2	245	Grilli, S.T.	12	141
Nettles, M.	3	242	Shi, S.	6	140
Sieh, K.	11	240	Kamataki, T.	8	137
Nott, J.	8	236	Meltzner, A.J.	3	137
Aster, R.C.	1	235	Pelinovsky, E.	26	135
Brudzinski, M.R.	1	235	Bernard, E.N.	13	132
Deshon, H.R.	1	235	Fryer, G.J.	8	132
Sipkin, S.	1	235	Oleskevich, D.A.	1	132
Bondevik, S.	9	231	Bryant, E.A.	14	127
Dawson, A.G.	11	219	Miranda, J.M.	9	127
Tappin, D.R.	12	216	Okal, E.	4	127
Thomson, R.E.	16	216	Sawai, Y.	9	127
Geist, E.L.	21	214	Yeh, H.	12	127
Imamura, F.	32	214	Smit, J.	2	125
Mangerud, J.	5	210	Song, T.-R.A.	2	125
Wang, K.	5	210	Kvenvolden, K.A.	1	124
Borrero, J.C.	19	209	Shimokawa, K.	3	124
Gonzalez, F.I.	12	207	Stein, S.	4	123
Atwater, B.F.	9	205	Schindele, F.	11	119
Goff, J.	10	205	Witter, R.C.	7	119
Svendsen, J.I.	4	196	Bilham, R.	4	118
Bock, Y.	5	190	Crook, K.A.W.	6	118
Goff, J.R.	17	187	Armigliato, A.	10	115
Avouac, J.-P.	5	185	Felton, E.A.	6	115
Beardsley, B.	1	182	Covey, C.	1	114
Lentz, S.	1	182	Morrison, D.	2	114
Pawlowicz, R.	1	182	Toon, O.B.	1	114
Piatanesi, A.	22	182	Turco, R.P.	1	114
Hirata, K.	16	180	Zahnle, K.	1	114
Heinrich, P.	12	178	Hemphill-Haley,E.	5	108
Iturralde-Vinent, M.A.	4	175	Berges, J.	1	107
Hutchinson, I.	8	174	Park, J.	4	107
Kelsey, H.M.	10	172	Nelson, A.R.	9	106
Scheffers, A.	18	172	Prescott, J.R.	1	105
Prawirodirdjo, L.	3	167	Robertson, G.B.	1	105

Co-authorship Index

Co-authorship Index (CAI) has been firstly elaborated by Schubert and Braun (1986), and is obtained by calculating proportionally the publications by single, two, multi- and mega-authored papers for different nations or for different sub-disciplines. This methodology is similar to the Activity Index (Frame, 1977). CAI = 100 indicates that the number of publications corresponds to the average within a co-authorship pattern. CAI > 100 reflects higher than the average, and CAI < 100 indicates lower than the average (Guan and Ma 2007). Here the papers have been divided into four categories according to the number of authors, namely single-authored, two-authored, multi-authored papers with three to four authors, and mega-authored papers with five or more authors. It is clearly evident from Figure 4 that the CAI for mega-authored papers for the countries Japan, India, Italy and France is more than the average. The relatively higher CAI of mega-authored papers for these countries indicates that their scientists prefer to work in larger groups when compared to scientists in the USA, United Kingdom and Australia. The CAI which is lower than other countries indicates that the scientists in these three places prefer to work in smaller groups.

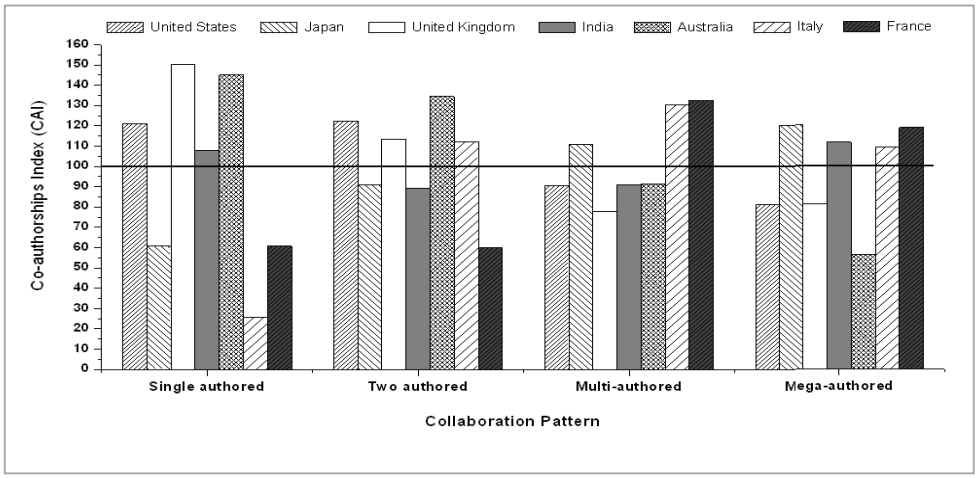

Figure 4: Co-authorships Trend in Tsunami Publications during 1997-2008

Highly Cited Publications

The number of citations does not actually indicate the quality of an article, but is a measure of its impact or visibility (Chiu 2007). The most cited publication "The great Sumatra-Andaman earthquake of 26 December 2004" by Lay et al. published in *Science* has been cited 235 times until 2008 since its publication in 2005. Table 6 gives a list nine highly cited Tsunami publications indexed and cited in *Scopus*^{TM}.

Table 6: The Most Cited Tsunami Publications as per *Scopus*™ Database

Rank	Bibliographic details	Number of Citations
1	Lay, T., Kanamori, H., Ammon, C.J., Nettles, M., Ward, S.N., Aster, R.C., Beck, S.L., Bilek, S.L., Brudzinski, M.R., Butler, R., Deshon, H.R., Ekstrom, G., Satake, K., Sipkin, S. (2005). The great Sumatra-Andaman earthquake of 26 December 2004. Science. Vol. 308 (5725): pp. 1127-1133	235
2	Pawlowicz R., Beardsley B., Lentz S. (2002). Classical tidal harmonic analysis including error estimates in MATLAB using TDE. Computers and Geosciences. Vol. 28 (8): pp. 929-937	182
3	Iturralde-Vinent M.A., MacPhee R.D.E. (1999). Paleogeography of the Caribbean region: Implications for cenozoic biogeography. Bulletin of the American Museum of Natural History. (238): pp. 1-72	156
4	Oleskevich D.A., Hyndman R.D., Wang K. (1999). The updip and downdip limits to great subduction earthquakes: Thermal and structural models of Cascadia, south Alaska, SW Japan, and Chile. Journal of Geophysical Research B: Solid Earth. Vol. 104 (B7): pp. 14965-14991	132
5	Kvenvolden K.A. (1999). Potential effects of gas hydrate on human welfare. Proceedings of the National Academy of Sciences of the United States of America. Vol. 96 (7): pp. 3420-3426	124
6	Smit J. (1999). The global stratigraphy of the Cretaceous-Tertiary boundary impact ejecta. Annual Review of Earth and Planetary Sciences. Vol. 27: pp. 75-113	117
7	Toon O.B., Zahnle K., Morrison D., Turco R.P., Covey C. (1997). Environmental perturbations caused by the impacts of asteroids and comets. Reviews of Geophysics. Vol. 35 (1): pp. 41-78	114
8	Berges J. (2002). Controlled nonperturbative dynamics of quantum fields out of equilibrium. Nuclear Physics A. Vol. 699: pp. 847-886	107
9	Prescott J.R., Robertson G.B. (1997). Sediment dating by luminescence: A review. Radiation Measurements. Vol. 27: pp. 893-922	105

Document Types

The distribution of document type identified by *Scopus*™ was analysed. From this analysis, 12 document types were found. The journal article was the most frequently used document type comprising 2724 (62.79%) items with 17199 (81.48%) citations of the total publications, followed by conference papers (691, 15.91%) with 1253 (5.94%) citations, reviews (373, 8.60%) with 1980 (9.38%) citations. Other document types were Notes (181, 4.17%) with 230 (1.09%) citations, Editorials (134, 3.09%) with 121 (0.57%) citations, Short Surveys (123, 2.84%) with 217 (1.03%) citations, Letters (76, 1.75%) with 104 (0.49%) citations, Erratum (8, 0.18%) with 3 (0.01%) citations, and Conference Reviews (16, 0.37%), Business Articles (6, 0.14%), Articles in Press (5, 0.12%) and Book (1, 0.02%) received no citations.

Preference of Channels of Communication by the Scientists

The distributions of publications on Tsunami were spread over a variety of publication media. The leading journals preferred by the scientists were: *Geophysical Research Letters* with 130 publications and received 1270 citations, *Marine Geology* with 64 publications (842 citations), *Journal of Geophysical Research B: Solid Earth* with 39 publications (833 citations), and *Sedimentary Geology* with 53 publications (642 citations). Table 7 presents a list of the highly cited journals by the scientists in Tsunami research.

Table 7: Highly Cited Journals in Tsunami Research

Journal	No. of Publications	No. of Citations	Average
Geophysical Research Letters	130	1270	9.77
Marine Geology	64	842	13.16
Journal of Geophysical Research B: Solid Earth	39	833	21.36
Sedimentary Geology	53	642	12.11
Pure and Applied Geophysics	47	611	13.00
Natural Hazards	77	555	7.21
Geology	36	521	14.47
Nature	17	494	29.06
Science	11	409	37.18
Journal of Waterway, Port, Coastal and Ocean Engineering	25	364	14.56
Bulletin of the Seismological Society of America	41	352	8.59
Earth, Planets and Space	41	347	8.46
Journal of Food Protection	9	320	35.56
Geophysical Journal International	33	286	8.67
Bulletin of the Geological Society of America	12	213	17.75
Natural Hazards and Earth System Science	36	210	5.83
Journal of Coastal Research	18	208	11.56
Computers and Geosciences	5	202	40.40
Earth and Planetary Science Letters	24	198	8.25
Journal of Fluid Mechanics	13	198	15.23
Quaternary International	18	194	10.78
Reviews of Geophysics	3	178	59.33
Current Science	52	176	3.38
Bulletin of the American Museum of Natural History	1	156	156.00
Journal of Geophysical Research C: Oceans	27	147	5.44
Holocene	12	147	12.25
Marine and Petroleum Geology	6	135	22.50
Bulletin of Volcanology	10	134	13.40
Quaternary Research	6	129	21.50
Quaternary Science Reviews	8	128	16.00
Annual Review of Earth and Planetary Sciences	2	125	62.50
Journal of Volcanology and Geothermal Research	14	120	8.57
Sedimentology	6	115	19.17
Nuclear Physics A	1	107	107.00
Journal of Physical Oceanography	11	106	9.64
Journal of Seismology	11	100	9.09

Keyword Analysis

Keywords are one of the best scientometric indicators to understand and grasp instantaneously the thought content of the papers and to find out the growth of the subject field. Analyzing the keywords appeared either on the title or assigned by the

indexer or the author himself will facilitate knowing in which direction the knowledge grows. The keywords appeared in the Index Keywords field in *Scopus*™ database of Tsunami publications were analysed. The highly cited keywords were: Tsunami (2890) with 17031 citations, Human (1279) with 4653 citations, Earthquake (770) with 6507 citations, Natural Disasters (652) with 2032 citations, Eurasia (628) with 2710 citations, Disaster (625) with 2523 citations, Asia (547) with 2200 citations, Indonesia (433) with 1121 citations, Indian Ocean (333) with 1769 citations, Adult (325) with 1655 citations, Disaster Planning (323) with 827 citations and Thailand (314) with 1322 citations. It is clearly evident from the data that the keywords in the range 1 to 15 have received more than 63% citations. Table 8 gives the keywords range and citations. Table 9 gives the frequency appeared in the 'Index Keyword field' of *Scopus*™ database and citations.

Table 8: Number of Keywords in a Publication and the Citations Received

No of Keywords	No. of Citations	% of Citations	Cumulative %	No of Keywords	No. of Citations	% of Citations	Cumulative %
0	1376	6.52	6.52	36	67	0.32	94.56
1	117	0.55	7.07	37	127	0.60	95.16
2	102	0.48	7.56	38	54	0.26	95.41
3	486	2.30	9.86	39	96	0.45	95.87
4	1252	5.93	15.79	40	18	0.09	95.95
5	1059	5.02	20.81	41	65	0.31	96.26
6	1581	7.49	28.30	42	44	0.21	96.47
7	1188	5.63	33.93	43	99	0.47	96.94
8	853	4.04	37.97	44	109	0.52	97.46
9	744	3.52	41.49	45	41	0.19	97.65
10	926	4.39	45.88	46	13	0.06	97.71
11	837	3.97	49.85	47	132	0.63	98.34
12	717	3.40	53.24	48	120	0.57	98.91
13	704	3.34	56.58	49	1	0.00	98.91
14	698	3.31	59.89	50	14	0.07	98.98
15	836	3.96	63.85	51	14	0.07	99.04
16	699	3.31	67.16	52	19	0.09	99.13
17	525	2.49	69.65	53	11	0.05	99.19
18	399	1.89	71.54	55	11	0.05	99.24
19	368	1.74	73.28	56	4	0.02	99.26
20	402	1.90	75.18	57	19	0.09	99.35
21	301	1.43	76.61	58	0	0.00	99.35
22	339	1.61	78.22	59	51	0.24	99.59
23	261	1.24	79.45	60	1	0.00	99.59
24	338	1.60	81.05	63	5	0.02	99.62
25	445	2.11	83.16	67	11	0.05	99.67
26	339	1.61	84.77	68	7	0.03	99.70
27	429	2.03	86.80	69	1	0.00	99.71
28	162	0.77	87.57	70	53	0.25	99.96
29	328	1.55	89.12	71	2	0.01	99.97
30	159	0.75	89.88	76	3	0.01	99.98
31	250	1.18	91.06	77	0	0.00	99.98
32	80	0.38	91.44	84	3	0.01	100.00
33	194	0.92	92.36	85	1	0.00	100.00
34	197	0.93	93.29	93	0	0.00	100.00
35	200	0.95	94.24				

Table 9: Keywords Frequency and their Citations appeared in Tsunami Publications in the 'Index Keywords' as per *Scopus*^{TM} Database

Keyword	Frequency	No. of Citations	Keyword	Frequency	No. of Citations
Tsunami	2890	17031	North America	141	666
Human	1279	4653	Numerical Model	139	718
Earthquake	770	6507	Wave Propagation	134	664
Natural Disasters	652	2032	WHO	132	185
Eurasia	628	2710	Holocene	129	1372
Disaster	625	2523	Child	126	470
Asia	547	2200	Japan	117	638
Indonesia	433	1121	Bathymetry	115	842
Indian Ocean	333	1769	Orga. & Management	115	143
Adult	325	1655	Southern Europe	111	668
Disaster Planning	323	827	Hazard Assessment	110	697
Thailand	314	1322	Landslides	109	915
Male	282	1426	Submarine Landslide	106	1312
United States	275	1588	Disaster Management	105	226
Mathematical Models	274	1571	Sedimentation	105	1191
Sri Lanka	273	946	Sea Level	103	523
Female	266	1290	Hydrodynamics	101	637
India	250	1140	Tectonics	101	866
Coastal Zones	247	1184	Environmental Impact	98	398
Computer Simulation	243	1138	Subduction Zone	97	1107
Southeast Asia	240	1081	Atlantic Ocean	96	675
Disasters	216	241	Middle Aged	96	611
Risk Assessment	197	936	Public Health	96	256
Relief Work	196	331	Water Waves	96	412
South Asia	192	712	Coastal Engineering	93	242
Seismology	183	1729	Far East	93	345
Europe	182	1111	Remote Sensing	93	261
World	175	1857	Sumatra Earthquake 2004	93	588
Oceanography	171	751	Earthquake Event	92	291
Pacific Ocean	166	1293	Eastern Hemisphere	92	720
Earthquake Effects	146	790	Earthquake Magnitude	90	353

CONCLUSION

This paper has analysed 4338 publications on Tsunami indexed and cited in the *Scopus* ^{TM} database during 1997-2008. The highest number of publications (1053) which received 4022 citations were published in 2005. The average number of publications per year was 361.50. There is a declining trend of publications from 2006 to 2008. The analysis indicates that USA is leading in the Tsunami research with 1081 (24.92%) publications which received 8534 (40.43%) citations, followed by Japan with 427 (9.84%) publications (2668, 12.64% citations), United Kingdom with 320 (7.38%) publications (2067, 9.79% citations) and India with 294 (6.78%) publications (857, 4.06% citations). The authorship and collaboration trend is towards multi-authored papers. Researchers in Japan, India, Italy and France prefer to work in larger groups when compared to scientists in USA, United Kingdom and Australia whose researchers prefer to work in smaller groups. Researchers preferred to publish in journals and the highly cited journals in the field were: *Geophysical Research Letters* with 130 publications, *Marine Geology* with 64 publications, *Journal of*

Geophysical Research B: Solid Earth with 39 publications and *Sedimentary Geology* with 53 publications.

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