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Analysis on earthquake databases of the Sabah region and its application for seismic hazard assessment using the IMS data of the CTBTO

Muhammed Zulfakar Zolkaffly & Faisal Izwan Abdul Rashid

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POSTER

NUKLEAR MALAYSIA
Malaysia CTBT National Data Centre (MY-NDC)
Malaysian Nuclear Agency

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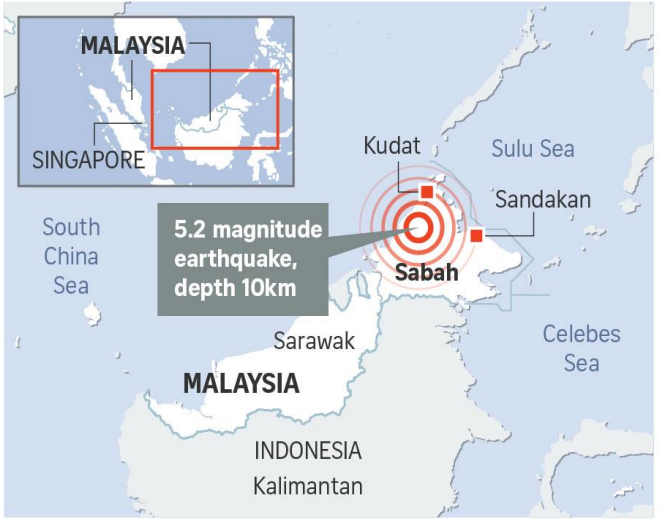
Unlike the Peninsular Malaysia which is classified as a seismically stable, Sabah state in eastern Malaysia is characterized by common seismological activity. Generally an earthquake of moderate magnitude is experienced at an interval of roughly every 20 years, originating mainly from two major sources, either a local source (Ranau and Lahad Dato) or a regional source (Kalimantan and South Philippines subductions).

It was reported that from the 121 year record dating back from 1897 until 2018, the first inland earthquake recorded with a magnitude of more than 6 Richter magnitude was in Lahad Datu back in 1923-08-11 with magnitude 6.3. The 2015 Ranau earthquake was the 4th inland earthquake with very strong intensity and had caused much damage especially to badly built structures followed with over 250 aftershocks.*



Source: UNITED STATES GEOLOGICAL SURVEY
STRAITS TIMES GRAPHICS

Source: https://www.straitstimes.com/asia/se-asia/over-100-mount-kinabalu-climbers-rush-to-safety-after-earthquake-strikes-sabah

*source: https://www.astroawani.com/berita-malaysia/remembrance-2015-sabah-earthquake-learning-past-better-future-209418

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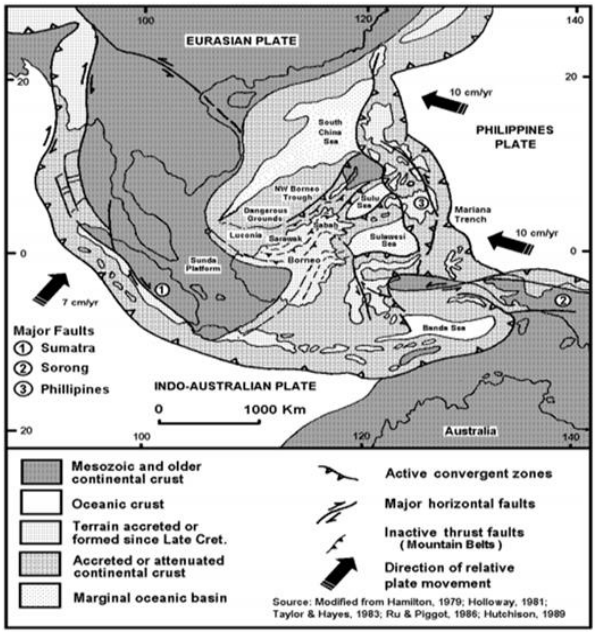
ABSTRACT

- Seismicity record of Sabah shows the presence of two distinctive seismic zones in the region, which are Ranau in Kota Kinabalu and Lahad Datu.
- The IMS network setup by the CTBTO has successfully detected seismic events occurred in the region for the past decades.
- This study presents data analysis of earthquake events occurred around the region from 2002 to 2020, which were recorded by the IMS seismic network. The subsequent preliminary analysis of earthquake hazard utilizing these IMS data have enabled the quantification of seismic hazard of the region in terms of recurrence periods and probabilities of occurrence of earthquake at any given magnitude.
- The findings shows that the IMS data can be used for earthquake sequence analyses of the region and play an important role in seismological research.

Major tectonic in Malaysia



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INTRODUCTION

- The data recorded by a globally distributed network of IMS seismic stations could be used to improve the accuracy and timeliness of analysis on potentially damaging earthquake events.
- This study presents the results of data analysis of 19 years recent earthquakes in Sabah from 2002 to 2020 recorded by the IMS seismic stations. We will discuss on the important seismicity parameters, including the epicentral and magnitude distribution that were obtained from the Reviewed Event Bulletin (REB). The IMS database that we compiled also were compared with the databases of the U.S. Geological Survey (USGS) and Incorporated Research Institutions for Seismology (IRIS).
- Finally, we present the preliminary assessment of earthquake hazard for Sabah using the IMS database compiled earlier. The analysis was performed using statistic theory of extreme values from Gumbel, where the results have enabled the quantification of earthquake hazard in Sabah in terms of recurrence periods and probabilities of occurrence at any given magnitude.

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METHODS

Analysis of Earthquake Events

- The seismic events occurred in Sabah region from 2002 to 2020 were obtained from the IDC REB, where such events were screened to ensure the reported events correctly fall within study of region.
- This compiled IMS database and its seismicity parameters including location, depth and seismic phases were compared with the databases of the USGS and IRIS.
- The deviation of epicenters of all events recorded by the USGS and IRIS networks relative to the epicenter located by the CTBT IMS detection was also calculated.

Preliminary Analysis of Earthquake Hazard

- The preliminary analysis was performed using statistical theory of extreme values developed by Gumbel.
- If compared with other methods requiring the whole data set, and rarely completely reported, the Gumbel's need only part of the event data, such as, the largest (i.e. extremes) earthquakes.
- The IMS data represent a continuous and complete set of annual maximum magnitude events, suitable for the application of such method to quantify earthquake hazard in terms of recurrence periods and probabilities of occurrence at any given magnitude.

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RESULTS

- The IMS recorded **33 moderate events**, ranging from 3.3 to 5.2 mb, originated in the region of Sabah from January 2002 to June 2020
- 2015 has recorded the highest number of earthquake occurrence, where the IMS recorded event on June 4, 2015 23:15:43 UTC is consistent with the Ranau's moderate earthquake on June 5, 2015 7:15 am local time as reported by the Malaysia's local authority
- The parameters of seismic event detected by USGS and IRIS networks in Ranau on June 5, 2015 are also identical to the one recorded by the CTBT IMS network

YEAR	CTBT IMS Seismic Network						
	Event ID	Date	Time	Latitude	Longitude	Magnitude	Depth (KM)
2020	18767431	14/04/2020	20:04:22	5.0212	118.9558	mb 3.6	0
2019	17680942	03/08/2019	15:31:06	6.2831	117.2185	mb 3.6	0
2018	15530461	08/03/2018	13:06:10	5.8856	116.5306	mb 4.4	0
	15848813	27/05/2018	7:53:42	5.2794	119.0089	mb 3.8	0
	15916404	16/06/2018	7:47:58	1.0666	111.3856	mb 3.8	0
2017	14228945	26/03/2017	9:30:49	4.7966	118.7287	mb 3.7	53
	14888716	24/09/2017	0:25:23	5.9464	118.3581	mb 3.5	0
2016	13497338	26/08/2016	1:39:32	6.4172	117.3407	mb 3.6	0
2015	11783042	19/03/2015	21:56:00	5.4795	118.3777	mb 3.8	0
	11997735	14/05/2015	10:25:07	1.8141	110.5797	mb 3.6	0
	12047012	04/06/2015	23:15:42	6.039	116.6377	mb 5.2	0
	12048513	05/06/2015	13:12:14	6.6386	117.191	mb 3.7	0
	12048801	05/06/2015	15:13:32	6.0524	116.6861	mb 3.9	0
	12050340	06/06/2015	5:45:13	6.2528	116.8675	mb 4.1	0
	12068968	12/06/2015	18:25:34	6.4085	117.3888	mb 3.4	0
	12068970	12/06/2015	18:29:24	6.0878	116.8661	mb 4.4	75
	12098600	23/06/2015	9:32:34	5.9739	116.5596	mb 3.7	49
	12199515	26/07/2015	10:04.9	6.2731	117.0466	mb 3.9	0
2014	10715051	14/04/2014	20:42:03	4.5645	117.7927	mb 3.4	0
	10471451	01/02/2014	11:35:08	6.095	116.6187	mb 4.1	0
2013	10099555	19/09/2013	21:50:37	5.6921	116.223	mb 3.6	0
	9440838	29/01/2013	1:04:30	5.1358	118.7193	mb 4.0	0
2012	8726575	28/05/2012	16:44:08	4.7371	118.3378	mb 4.1	0
2011	-	-	-	-	-	-	0
2010	6607825	21/08/2010	19:43:27	5.4801	118.5899	mb 3.5	0
2009	-	-	-	-	-	-	0
2008	4536681	10/01/2008	13:18:35	4.2583	116.5442	mb 3.6	0
2007	4428540	23/10/2007	20:34:39	5.6865	119.2532	mb 4.3	0
2006	3550325	06/02/2006	14:54:07	5.1248	118.8151	mb 3.6	0
	3674353	22/04/2006	2:01:25	6.0392	117.5982	mb 3.7	0
	3859855	28/09/2006	15:11:34	6.4085	118.0916	mb 3.7	0
2005	3249883	23/05/2005	19:58:12	6.2446	117.713	mb 4.3	0
2004	-	-	-	-	-	-	0
2003	1978643	02/11/2003	8:43:19	6.2718	117.5447	mb 3.5	0
	1852956	22/08/2003	18:01:00	5.8225	119.2862	mb 3.3	0
2002	1328028	06/10/2002	21:03:24	5.9584	117.8815	mb 3.8	0

U.S. Geological Survey (USGS)							
Year 2018		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Ranau	08/03/2018	13:06:13	6.0846	116.5853	mww 5.2	10
2	Sandakan	05/01/2018	0:40:33	5.9504	117.7198	mb 4.3	10
Year 2017		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Lahad Datu	26/03/2017	9:30:48	4.9334	118.7791	mb 4.6	33.96
Year 2016		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Lahad Datu	04/03/2016	0:43:36	4.9182	118.4359	mb 4.1	34.96
Year 2015		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Sandakan	19/03/2015	21:56:07	5.5346	118.6135	mb 4.1	50.77
2	Ranau	04/06/2015	23:15:44	5.9867	116.5409	mww 6	10
3	Ranau	05/06/2015	15:13:36	6.1402	116.7228	mb 4.4	18.23
4	Ranau	06/06/2015	5:45:15	6.1416	116.6689	mb 4.6	10
5	Ranau	12/06/2015	18:25:37	6.1504	116.692	mb 4.4	15.01
6	Ranau	12/06/2015	18:29:16	6.2053	116.6814	mb 5.3	7.25
7	Ranau	23/06/2015	9:32:31	6.1277	116.5537	mb 4.5	15.32
8	Ranau	26/07/2015	16:10:12	6.2782	116.8568	mb 4.6	14.96

Incorporated Research Institutions for Seismology (IRIS)							
Year 2018		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Borneo	3/8/2018	13:06:13	6.04	116.61	mb 5.2	10
Year 2017		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Borneo	3/26/2017	9:30:48	4.93	118.78	mb 4.6	33.96
Year 2016		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Borneo	3/4/2016	0:43:35	4.92	118.44	mb 4.1	34.96
Year 2015		Date	Time	Latitude	Longitude	Magnitude	Depth
1	Borneo	3/19/2015	21:56:04	5.6182	118.6962	mb 4.1	35
2	Borneo	6/4/2015	23:15:45	6.0439	116.6651	Mw 6.0	18.1
3	Borneo	6/5/2015	13:12:16	6.2967	116.6288	mb 3.5	10
4	Borneo	6/5/2015	15:13:35	6.2153	116.8726	mb 4.4	10
5	Borneo	6/6/2015	5:45:15	6.188	116.7836	mb 4.6	10
6	Borneo	6/12/2015	18:25:39	6.039	116.5783	mb 4.4	35
7	Borneo	6/12/2015	18:29:18	6.0674	116.621	Mw 5.2	28.3
8	Borneo	6/23/2015	9:32:33	6.0491	116.5472	mb 4.5	35
9	Borneo	7/26/2015	16:10:11	6.0664	116.8082	mb 4.6	10

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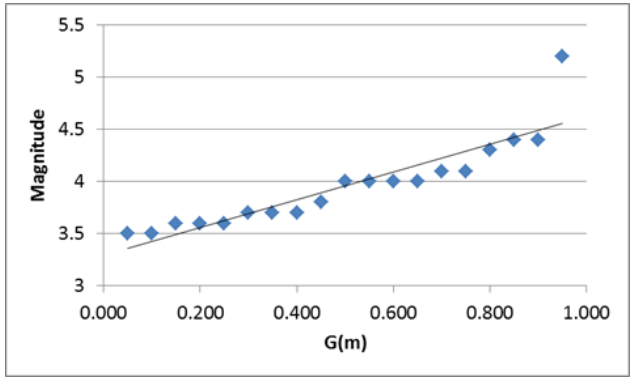
RESULTS

Line of Expected Extreme (LEE)



- The mean line of expected extreme (LEE) is drawn to study the mean return periods of the largest possible earthquakes with their probability of occurrence

Magnitude	Yearly Expected Number (N_m)	Return Period (T_m)
3	6.53257	0.153
3.5	1.86797	0.535
4	0.53414	1.872
4.5	0.15274	6.547
5	0.04367	22.897
5.5	0.01249	80.074
6	0.00357	280.031
6.5	0.00102	979.312
7	0.00029	3424.806
8	0.00002	41885.712

- The quantified earthquake yearly numbers and their return period for different magnitude indicates that as return period increases, frequency of earthquake occurrences decreases

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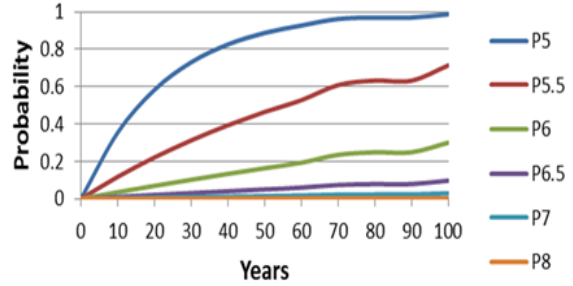
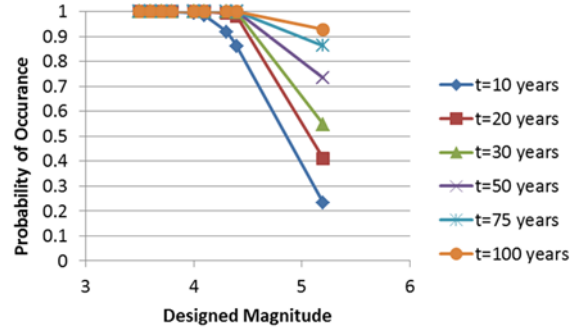
RESULTS

Variation of Probability With Year



Earthquake Hazard for Different Period



- The relation between of calculated yearly numbers of earthquakes, their return periods and the quantified earthquake hazard is illustrated in these figures
- It is suggested that within 100 year period the probability of occurrence of larger magnitude earthquakes decrease with time

Earthquake Recurrence Period with 90% probability

Magnitude (m)	Return Period (years)	Recurrence Period (years)
3	0.153	0.69
3.5	0.535	2.40
4	1.872	8.40
4.5	6.547	29.39
5	22.897	102.78
5.5	80.074	359.42
6	280.031	1256.96
6.5	979.312	4395.77
7	3424.806	15372.71
8	41885.712	188009.73

- One can estimate expected period within which at least one earthquake of any given magnitude will occur with any specified probability
- For example, recurrence period for at least one earthquake of magnitude *m* within a probability of 90% is summarized by above table

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CONCLUSIONS

- During the period of 2002-2020, the IMS network had detected 33 earthquakes in the region of Sabah, identical to those recorded by the USGS and IRIS.
- The IMS earthquake data sets used in this study leads to compatible results that demonstrate clear consistency with the stability postulate from which distributions of extremes are deduced.
- The results of preliminary analysis has enabled earthquake hazard in Sabah to be quantified in terms of recurrence periods and probabilities of occurrence of earthquake at any given magnitude.
- Present work shows that IMS data can be used for earthquake sequence analyses of the region and play an important role in seismological research.