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CIVIL AND SCIENTIFIC APPLICATION OF IMS NETWORK DATA IN EARTHQUAKE HAZARD ASSESSMENT

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International Monitoring System (IMS), using four technologies – seismic, hydroacoustic, infrasound and radionuclide. While awaiting entry-into-force, the IMS is operating in test mode yet, even now, monitoring data have potential use among the scientist for the social welfare means. Contribution to the earthquake hazard and related earthquake engineering determinations is a big development and knowledge expansion of the one of the cited technology i.e. seismic. In this direction Indonesian region bounded by 14°S–10°N and 93–141°E, which is one of the most seismically Trans-Asian and Circum-Pacific belts type active plate regions of the world where large to great earthquakes have occurred during the past hundred years have been considered. Nineteen years recent earthquake data from June 13, 1999 to July 10, 2017 have been taken from International Monitoring System (IMS) Network setup by Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Vienna Austria. These data analyses shows that earthquake occurrences agrees with the Gumbel's Type I extreme distribution function and has been applied to analyses those maximum magnitude data with a satisfactory degree of correlation (0.96). The earthquake hazard that existed in Indonesian region been quantified in terms of recurrence periods and probabilities of occurrence of earthquake of any given magnitude. This investigation indicates that the most probable largest annual earthquakes are close to 6.0. Also, most probable earthquake that may occur in an interval of 50 years is estimated as 6.8. Other medium to large size earthquakes which are expected to occur in this region has been predicted that may help in engineering investigations at particular site and decision making problems if planning to develop certain region for infrastructural activities.

INTRODUCTION

The International Monitoring System (IMS) uses four monitoring technologies as seismic, hydroacoustic, infrasound and radionuclide monitoring technologies are capable of detecting evidence of nuclear explosions underground, in water (ocean) and in the atmosphere. In order to monitor compliance with the Comprehensive Nuclear-Test-Ban Treaty, these verification technologies, together with the data, technologies and products of the International Data Centre, have potential civil and scientific applications. This can provide significant benefits to States and the international scientific community [1]. For example, highly sensitive hydrophone arrays and seismic T-phase stations installed in the oceans have observed an increasing number of icebergs breaking off the Antarctic ice shelves and sliding on icy or rocky surfaces. This occurrence is indication of global warming. Further, submarine volcanoes, earthquakes and underwater explosions are also recognized and positioned, paying to a better appreciative of hydroacoustic wave propagation.

In the case of infrasound technology, the sensitive IMS infrasound arrays and the improved processing system have been developed at the IDC and various NDCs. These provide a unique tool to detect, locate and characterizes natural atmospheric phenomena on a global scale. Hence, could be used for atmospheric transport modeling.

The IMS radionuclide network also provides a new level of sensitivity and coverage through the worldwide, quasi-continuous, low level data it can deliver on levels of natural or artificial radioisotopes. For example, natural radioisotopes originating from the crust and from the upper atmospheric layers may provide clues on the vertical mixing and interaction of air masses on a global scale, of possible interest to global warming investigations. Continuous radionuclide monitoring at very low detection thresholds will allow detection and tracking of accidental releases. This will help emergency preparedness efforts in detection, modelling and decision support by providing predicted deposition rates.

The seismic network of IMS is very exhaustive and important one. Here, the Reviewed Event Bulletin (REB), which the PTS has been providing to the International Seismological Centre (ISC) since 2000, has contributed significantly to evaluations of earthquake magnitudes. To strengthen the collaboration between ISC and PTS for mutual benefits, ISC provide continuous data to IDC with access to its collected data from 2000 stations distributed over worldwide. Not only this IMS make it possible to enhance access to waveforms and phase data help to scientific community to improve 3-D topographies of the earth. This may allow to scientists to better understand the earth's internal structure. The combination of IMS seismic and infrasound data could be used for deep studies of solid earth and atmosphere for the prediction of impact of seismic hazard assessments in some areas of the globe for large earthquakes. Therefore we can say that IMS, IDC and OSI (On Site Inspection) are three main pillars of the of the verification regime. However, an OSI can be appealed only after entry into force of the CTBT.

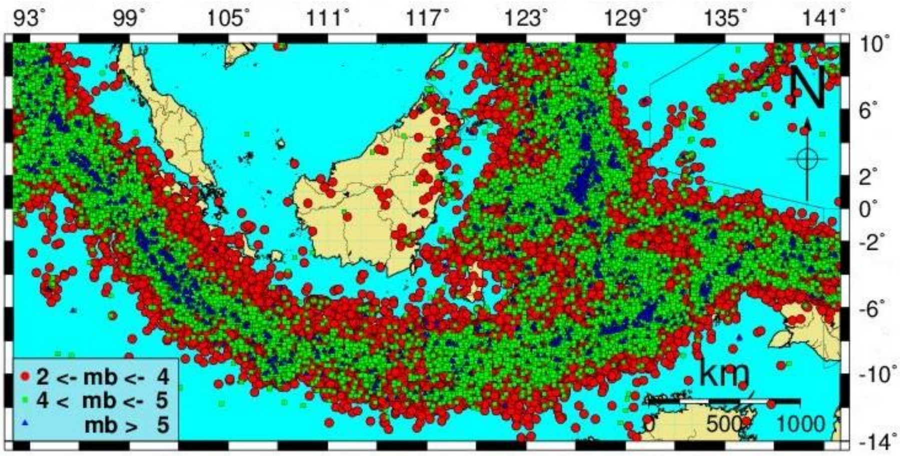

Figure 1: Seismicity map of the considered region using data recorded by (IMS) from 1999 to 2017

But, during the verification regime, the IMS technologies with its collected data have contributed a lot for civil and scientific applications beyond nuclear test detection, like tsunami warning, ocean discoveries [2], fisheries and seismic hazard assessment and earthquake forecasting. In the present study, contributions to the earthquake hazard and related earthquake engineering determinations have been taken for Indonesian region.

STUDY REGION AND SEISMICITY DATA

To understand an earthquake phenomenon and its associated risk in a region, a good database is important. We have used a very precisely located dataset taken by the International Monitoring System (IMS). Study investigates 19-years earthquake data from June 13, 1999 to July 10, 2017, with M ≥ 2.0 for the considered region bounded by −14°S–10°N and 93–141°E (Figure 1) taken from International Monitoring System (IMS) Network setup by Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Vienna Austria; which ensures a more reliable analysis.

METHODOLOGY AND FORMULATION OF ANALYSES

Gumbel's [3] formulated the extreme value theory have been used. Because, Gumbel's Type I, which uses extreme value statistics, need only part of the data (the largest earthquakes); when compared with methods requiring the whole data set, which is rarely completely reported. Therefore, CTBTO, IMS Network data is used because it represent a continuous and complete set of annual maximum magnitude events and is very useful for this purpose. The results are potentially useful and can be used to determine a variety of statistics including average recurrence periods of annual maximum magnitude earthquakes, probabilistic seismic hazard assessment in the region. Results are informative for seismic threat and related earthquake engineering determinations; usually require estimation of return periods or probabilities of exceedance of specific levels of design load criteria or extremal safety conditions.

RESULT AND DISCUSSION

Some important and useful analyses of the results have been summarized here in the form of tables (1 & 2). The results are potentially useful and can be used to determine a variety of statistics including average recurrence periods of annual maximum magnitude earthquakes, probabilistic seismic hazard assessment in the region

Table 1. Estimated Gumbel's Parameters α and β

Statistics	Value
Slope(−β)	−4.95
β	4.95
Intercept(ln(α))	29.69
α	7837962254587.30

Table 2: Design earthquake Recurrence Period with 89 % probability

Mag. (m)	Return Period (years)	Recurrence Period (years)
5.5	0.09	0.19
6.0	1.01	2.23
6.5	31.66	69.88
7.0	142.59	314.76
7.5	1694.27	3739.72
8.0	20130.83	44434.29
8.5	239188.67	527955.16

The histories of maximum earthquake magnitude recorded by IMS networks have been taken for quantifying the earthquake hazard (Table 1 & 2) for the considered region. The statistics have been used to forecast, with any given confidence, recurrence periods in the considered region for earthquake of any given magnitude. Practical advantages of extreme value methods are well known.

Extreme values of a seismological variant are usually better known than the smaller events in a time series of data. The detailed knowledge of the parent distribution is not compulsory because the distribution of extremes depend on common asymptotic properties of the rare events in the tail of possible distributions of the variant.

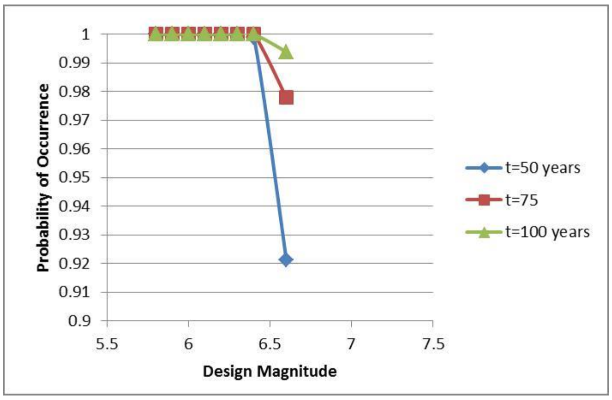

Figure 2: Earthquake hazard in Indonesia region for different period

The most probable annual maximum magnitude is equal to 6.0 and most probable 50-years maximum magnitude equal to 6.8 [4]. Thus the derived return periods may be used as quantitative measure of seismicity. However, this model doesn't tell anything about the earthquake characteristics. The estimates can be considered to be two ways reliable because on one way, the value of α and β which have been used to estimate the earthquake hazard and return periods do not change much for the short or long duration of data used and other, complete and reliable IMS data recording. The predicted values are useful for decision making planning for the builders of hydroelectric dams, construction industries and other engineering projects for human settlement or societal infrastructure development in the region.

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ЖЕРСІЛКІНУЛЕР ҚАУІПІН БАҒАЛАУЫНДА ХМЖ ЖЕЛІСІНІҢ ДЕРЕКТЕРІН АЗАМАТТЫҚ ЖӘНЕ ҒЫЛЫМИ ҚОЛДАНУ

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Төрт технологиясын – сейсмикалық, гидроакустикалық, инфрадыбыстық және радионуклидтік – қолданатын Халықаралық мониторингі жүйесі (ХМЖ) ЯСЖТШ күшіне енуін күтуде тестілік режимінде жұмыс істеп келеді, бірақта қазірде мониторингінің деректерін ғалымдар әлеуметті мақсатында пайдалануға мүмкін. Аталған бір технологиялардың – сейсмикалық – жерсілкінулердің қауіпін анықтауына және инженерлік сейсмологияға үлесі зор, білімді дамытатын және кеңейтетін болып табылады. Осы тұрғыда мақалада, соңғы жүз жылда қатты және өте қатты жерсілкінулер болған, Азия-Тынықмұхит белдеуі мен дөңгелек тынықмұхиттік белдеуінің сейсмикалық ең белсенді аймақтарының бірі болып табылатын, −14°о.е.–10°с.е. және 93°–141°ш.б. координаттарымен шектелетін, индонезиялық аумғы қарастырылады. Талдау үшін соңғы 19 жылдарының, 1999 ж. 13 маусымнан 2017 ж. 10 шілдеге дейін, Ядролық сынауларға жаппай тыйым салу туралы шартының ұйымымен, Вена, Австрия, орнатылған Халықаралық мониторингі жүйесінің (ХМЖ) жерсілкінулер туралы деректері алынған. Осы деректерді талдауы жерсілкінулер пайда болуы Гумбель функциясымен (I типіндегі экстремаль мәндері таралу) үйлесетінін және корреляцияның қанағаттандыратын дәрежесімен (0,96) максималь амплитудасымен деректерді талдауына жарамдылығын көрсеткен. Индонезиялық аймағы үшін жерсілкінудің қауіпі магнитуданың берілген мәндерінде қайталану және пайда болу ықтималдығы ретінде санды анықталған. Осы зерттеу ең ықтимал өте қатты жылсайынғы жерсілкінулер магнитудасы бойынша 6,0 жақын болуын көрсеткен. 50 жыл ауқымында болуы мүмкін өте қатты жерсілкінудің магнитудасы 6,8 ретінде бағаланады. Осы аймақта күтуге болатын басқа – орта және қатты – жерсілкінулері белгілі бір учаскелерде инженерлік ізденістерінде және белгілі бір аймақта инфрақұрылымды жобалау проблемасын шешуінде пайдалы болу мүмкін.

ГРАЖДАНСКОЕ И НАУЧНОЕ ПРИМЕНЕНИЕ ДАННЫХ СЕТИ МСМ В ОЦЕНКЕ ОПАСНОСТИ ЗЕМЛЕТРЯСЕНИЙ

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Международная система мониторинга (МСМ), использующая четыре технологии – сейсмическую, гидроакустическую, инфразвуковую и радионуклидную, – в ожидании вступления в силу ДВЗЯИ работает в тестовом режиме, но даже сейчас данные мониторинга могут быть использованы учеными в социальных целях. Вклад одной из упомянутых технологий – сейсмической, в определение опасности землетрясений и в инженерную сейсмологию является огромным, развивающим и расширяющим знания. В данном аспекте в статье рассматривается индонезийский регион, ограниченный координатами −14°ю.ш.–10°с.ш. и 93°–141°в.д., который является одним из самых сейсмически активных регионов Азиатско-Тихоокеанского пояса и кругового тихоокеанского пояса, где в последние сто лет возникали сильные и сильнейшие землетрясения. Для анализа взяты данные о землетрясениях за последние 19 лет от 13 июня 1999 г. до 10 июля 2017 гг. по сети МСМ, установленной Организацией по Договору о всеобъемлющем запрещении ядерных испытаний, Вена, Австрия. Анализ этих данных показал, что возникновение землетрясений согласуется с функцией Гумбеля (распределение экстремальных значений типа-I) и применимо к анализу данных с максимальной магнитудой с удовлетворительной степенью корреляции (0,96). Опасность землетрясения для индонезийского региона была определена количественно как повторяемость и вероятность их возникновения при заданных значениях магнитуды. Данное исследование показало, что наиболее вероятные сильнейшие ежегодные землетрясения близки по магнитуде к 6,0. Магнитуда наиболее вероятного сильнейшего землетрясения, которое может произойти в интервале 50 лет, оценивается как 6,8. Другие – средние и сильные землетрясения, – которые можно ожидать в данном регионе, могут быть полезными при инженерных изысканиях на определенных участках и в решении проблем планирования инфраструктуры в определенном регионе.