Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-01 Room:302 Time:May 27 09:45-10:00

Clustering of intraplate earthquakes and foreshock activity

Shin-ichi Noguchi[1*]

[1]NIED

Spatial and temporal clustering activity of earthquakes has the possibility of foreshocks or the initiation of future large events. We examine earthquake clusters for shallow intraplate earthquakes beneath the Japanese islands.

Pairs of earthquakes were linked through conditions based on origin time difference t and hypocentral distance d. We assume reasonably that the range of the time and distance of link-conditions depend on magnitude M, i.e., t(M) and d(M).

The result show that foreshock type clusters, which constitute with events occurring before the largest event, are larger in numbers than the mainshock-aftershock type clusters for clusters with many cluster members.

The 2004 Niigata-Chuetsu earthquake M6.8, the activity initiated from September 6, 2004, with the largest event M4.3, at the northern margin of the future rupture area was extracted as foreshocks. Also the 2008 Iwate-Miyagi Nairiku earthquake, the activity initiated from May 29, 2008, with the largest M4.8 in the Akita-ken was extracted as foreshocks. Because these foreshock activity occurred about half to 1.5 months before the mainshock around the future rupture area and the activity were not in continuous, it is difficult to identify clearly these activity as foreshocks. We show that the algorithm of linking method in this study has the possibility to detect objectively foreshock activity of large earthquake.

Keywords: earthquake cluster, single event, linking method, seismogenic layer, Omori-Utsu's formula

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-02 Room:302 Time:May 27 10:00-10:15

Earthquake Clustering Features Inferred from the Mean Proprieties of Interevent Times and Distances

Abdelhak Talbi[1*], Kazuyoshi Nanjo[1], Kenji Satake[1], Hamdache Mohamed[2]

[1]ERI, University of Tokyo, [2]CRAAG, Algeria

Interevent times between successive earthquakes are studied in space and time using data from Japan and southern California. The main objective is to depict general non-subjective clustering characteristics of interevent times that can be used to isolate clusters in observed seismicity. First, different declustering algorithms are applied to original data to estimate the residual background interevent time distribution. Then, clustering degree is measured using the distance between the obtained residual distribution and the whole distribution from the original data. Finally, the former analysis is carried out for different magnitude cutoffs and different time periods to take into account the completeness of magnitudes.

The preliminary results show that earthquake process is dominated by short and long term clustering. In contrast, the so-called background process occurs mainly at intermediate times. The same study applies to interevent distances and shows quite similar behavior in space.

The former analysis describes seismicity as the accumulation of local perturbations related to a unique mean field background processes characterized by the mean interevent time and the mean interevent distance. It highlights the importance of mean space-time proprieties in the estimation of objective and data inferred association measures between earthquake events. This study provides fundamental key tools for the elaboration of stochastic declustering strategies.

Keywords: Interevent times, Earthquake clustering, Background seismicity, Association measure

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-03 Room:302 Time:May 27 10:15-10:30

Investigation of the methods for prospective evaluation on earthquake activity (2nd)

Sadayuki Kitagawa[1], Masahiro Koya[1*], masaki honda[1], Takashi Yokota[2], Youhei Hasegawa[2], Kazuki Miyaoka[2], Tetsuro Imakiire[3], Hiroshi Yarai[3], Kunihiko Shimazaki[4]

[1]MEXT, [2]Japan Meteorological Agency, [3]Geospatial Information Authority, [4]Professor Emeritus of Tokyo University

Subcommittee for the Methods for Prospective Evaluation on Earthquake Activity was established under the Earthquake Research Committee (ERC) in August 2009 to contribute the upgrade of evaluation on the current seismic activity by ERC by extracting characteristic features of the past seismic activity for prospective analysis, and is developing an evaluation method for temporal seismicity variation.

ERC established the methods to evaluate the probability of aftershocks occurrence in August 1998 and JMA announces after a large earthquake that it expects aftershock activity based on the method. But the present procedure has some problems on (1) forecast accuracy, (2) public understanding of probability of aftershocks occurrence, and (3) availability of aftershock information soon after the main shock.

We investigate relationships among the mainshock magnitude, aftershock activity, the magnitude of the largest aftershock, presence of secondary aftershock, etc, for the past earthquakes and develop a prospective evaluation method for aftershock activity. Since the largest aftershock often takes place within 24 hours after the mainshock, it is fatally important to announce early the prospect of aftershock activity. Firstly, the aftershock activity and the magnitude of the largest aftershock can be predicted from the moment magnitude of the mainshock. However, in some cases the number of aftershocks associated with mainshocks with almost the same magnitude differs by about six times. So, it is considered to renew the information on the basis of the number of aftershocks within three hours after the mainshock. Renewal of information may be necessary when an aftershock with many secondary aftershocks occurs.

As the first case of prospective evaluation, we examined characteristic features of the past seismic swarm activities occurred off eastern Izu Peninsula that have many seismic and geodetic data and developed an evaluation method for the swarm activity. We introduced it at JpGU Meeting 2010 and published it as a report, "The prediction method for seismic activity off eastern Izu Peninsula," in September 2010.

Keywords: ERC, Subcommittee for the methods for prospective evaluation, Prospective evaluation on earthquake activity, Prospective method of aftershock activity, Seismic activity off eastern Izu Peninsula

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-04 Room:302 Time:May 27 10:45-11:00

The attempt of re-making Japan earthquake catalog based on Japan seismic networks

Sadayuki Kitagawa[1], Takashi Yokota[2], Hiroshi UENO[2*], Yoshiro Ohta[2], Committee on Earthquake Database of Japan University SeismicObservatory Networks[3], Katsuhiko Shiomi[4], Shin Aoi[4]

[1]MEXT, [2]JMA, [3]University Seismic Observatory Networks, [4]NIED

Japan Meteorological Agency is making catalog of earthquake which occurred in and around Japan since August, 1923.
Since October 1997, we calculate hypocenter location and magnitude based on seismic data of related organization (JMA, universities, NIED and so on). But, until September 1997, we calculated hypocenter location and magnitude with only JMA seismic data. Therefore, the difference of the detectability of the earthquakes is remarkable on the boundary of October, 1997. Moreover, the detection accuracy of hypocenter location is different every age, because hypocenter determination method is different every age.
Then, we assumed that we re-calculated location of earthquake which occurred before September 1997, based on seismic data of "Earthquake Database of Japan University Seismic Observatory Networks (Umino et al., 2007)", NIED and JMA.
In this time, we will introduce a part of the recalculation result.
Finally, we have a plan to publish final result by the Headquarters for Earthquake Research Promotion.

Reference

Umino, N., S. Hirahara, J. Nakajima, K. Katsumata, M. Kosuga, N. Hirata, T. Kanazawa, S. Sakai, F. Yamazaki, K. Matsumura, S. Kimura, K. Uehira, K. Goto, R. Matsu'ura and K. Tsumura, 2007, Earthquake Database of Japan University Seismic Observatory Networks, abstract of Japan Geoscience Union Meeting 2007, S144-003.

Keywords: Earthquake Catalog, Database of Japan University Seismic networks

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-05 Room:302 Time:May 27 11:00-11:15

Stress regime in the Philippine Sea slab and the asperity of the Kanto earthquake

Junichi Nakajima[1*], Akira Hasegawa[1], Fuyuki Hirose[2]

[1]Tohoku University, [2]Meteorological Research Institute

Two oceanic plates, the Philippine Sea and Pacific slabs, are subducting beneath Kanto, and seismogenesis are discussed in terms of dual subduction and resultant interaction (e.g., Wu et al., GRL, 2007; Uchida et al., EPSL, 2009; Nakajima et al., JGR, 2009; Nakajima and Hasegawa, JGR, 2010). However, stress regime in the Philippine Sea slab is poorly understood because of diverse seismicity as well as complex geometries of the two slabs. Here we determine focal mechanisms of small earthquakes in the Philippine Sea slab, and discuss stress regime with implications for the location of the Kanto asperity.

We determined focal mechanisms of 245 earthquakes occurring in the Philippine Sea slab from 2003 to 2010, and combined them with those determined by JMA. The obtained solutions indicate that stress regime is quite different between the northeast and southwest of the Tokyo bay. In the northeast, earthquakes nearby the slab surface occur under down-dip compressional stress regime, while those far from the slab surface have focal mechanisms with T axis in the down-dip direction. Earthquakes in the southwest have, however, T axis with a higher dip angle than the slab dip. Notably, such earthquakes occur only beneath the Kanto asperity.

Results of stres-tensor inversion show that sigma1 or sigma3 is parallel to the relative plate motion of the Philippine Sea slab, suggesting that stress regime in the slab is controlled mainly by the plate motion, not by local slab geometry. We further calculate the effect of a plate coupling along the Kanto asperity on intraslab stress regime. The obtained results suggest that stress regime generated by the plate coupling can explain the occurrence of the earthquakes with T axis with a higher dip angle. This spatial relation implies that the down-dip extension of the Kanto asperity is not locked at present and hence a large interplate earthquake would not occur there.

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-06 Room:302 Time:May 27 11:15-11:30

Numerical simulations of temperature field associated with subduction of two oceanic plates beneath Kanto district

Rumi Takagi[1*], Shoichi Yoshioka[2], Takumi Matsumoto[3]

[1]Dept. of Earth and Planetary Sci., [2]RCUSS, Kobe Univ., [3]Earthquake Research Department, NIED

1. Introduction

The Philippine Sea plate is subducting beneath the North American plate in the NNW direction, and the Pacific plate is subducting below the Philippine Sea plate in the WNW direction beneath the Kanto district. In this region, it is considered that complicated temperature and flow fields associated with subduction of the two oceanic plates are formed. Since the contact zone between the Philippine Sea and the Pacific plates exists beneath the Kanto district, low temperature field is considered to be realized. In fact, observed heat flow data which represent the underground temperature field is low in the Kanto district, which is remarkable in the Japanese islands.

In this study, we performed numerical simulations of temperature distribution associated with subduction of the plates along profiles parallel to the convergence direction of the Pacific or the Philippine Sea plates. By comparing heat flow estimated from thus obtained temperature distribution with the observed one, we focused on what kinds of features are brought by subduction of the two plates.

2. Models and Methods

In this study, using a 2-D box-type thermal convection model developed by Torii and Yoshioka (2007), we constructed a model in which the Philippine Sea plate subducts from 15Ma into the model region where the Pacific plate has already been subducting. We gave subduction velocity, referring to Sella et al. (2002). For the Pacific plate, we changed the age of the subducting plate according to Sdrolias et al. (2006). In addition, based on Nakajima et al. (2007, 2009) and Hirose et al. (2008), we gave the shape of the upper surface of the two oceanic plates and fixed it in the model as indicator of guides for the two subducting plates. We set a profile passing through the Kujukuri-hama for the direction of the Pacific plate subduction. On the plate boundary between the Philippine Sea and the North American plates, the 1923 Kanto earthquake (M7.9) occurred. Moreover, aseismic slow slip events off the east coast of the Boso Peninsula have been reported (Ozawa et al., 2003). So, to estimate the temperature field at the plate boundary is important. Then, we took three profiles passing through the areas of east and west asperities of the 1923 Kanto earthquake and the region of the aseismic slow slip events in the convergence direction of the Philippine Sea plate. For these four profiles, we calculated the temperature fields and heat flow, and compared the latter with the observed heat flow in each of these profiles. We used heat flow data of bore holes & heat probe (Tanaka et al., 2004; Yamano, 2004), BSR (Ashi et al., 1999, 2002), and Hi-net on the wells (Matsumoto, 2007).

3. Results

In our model, when the Philippine Sea plate subducts, where hot material associated with subduction of the Pacific plate is flowing into a mantle wedge, temperature decreases there. Furthermore, since the Philippine Sea plate plays a role as an obstacle, flow with high temperature yields near the upper surface of the Pacific plate at the down dip of the contact zone of the two oceanic plates, and the temperature rises there. Heat flow gradually decreases over time in association with subduction of the Philippine Sea plate, which fits the spatial distribution of the observed heat flow data well. In this presentation, we will also discuss the difference between the temperature fields in the areas of the two asperities of the 1923 Kanto earthquake and aseismic slow slip events on the plate boundary.

Keywords: subduction, temperature distribution, flow field, heat flow, Kanto earthquake, aseismic slow slip event

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-07 Room:302 Time:May 27 11:30-11:45

A hypocenter determination method with travel time difference between observation points

Kazuki Sakai[1], Yuji Yagi[1*], Yukitoshi Fukahata[2], Shin'ichi Sakai[3], Shigeki Nakagawa[3], Naoshi Hirata[3], Naoki Kimura[4], Tamotsu Aketagawa[5]

[1]Univ. Tsukuba, [2]DPRI, Kyoto Univ., [3]ERI, Univ. Tokyo, [4]NEID, [5]HSRI, Kanagawa Pref.

A hypocenter determination problem from observed seismic wave data has been one of the most important issues for seismology. In the hypocenter determination process, model errors originated from earth model uncertainty should be most important, because it is well recognized that errors due to uncertainty of velocity structure model can severely bias the result in the hypocenter determination. Considerable efforts were made to obtain more precise velocity structure, and then accuracy of hypocenter determination has been improved. However, we never obtain the true velocity structure model, and never calculate a theoretical travel time with the true velocity structure model. So in this study, we developed new hypocenter determination method so as to mitigate the model errors due to uncertainty of velocity structure model.

In general, the model errors correlate with not only location of hypocenter but also location of observation point. Taking the difference between the observation equations for a pair of observed points, we mitigate the effect of the model error. First, we constructed an observation equation for each station with the model error term, obtained an equation for location of hypocenter by taking the difference between the observation equations for a pair of observed points, and then determined location of hypocenter using the difference equation. The model error correlations among observation points should be mitigate in the difference equation.

We first made a synthetic test to compare the new formulation with the traditional formulation. We computed the synthetic travel time with 2.5 D structure model, and then determined location of hypocenter with simplified layered structure model. The results show that the estimation errors significantly mitigated under the new formulation. We next applied the new formulation to the JMA unified data of aftershocks of the 2004 Mid-Niigata prefecture earthquake, and to travel time observed MeSO-net in aftershocks of the 2010 northeast Chiba prefecture earthquake. From distribution of the 2004 Mid-Niigata prefecture earthquake, the fault plane dipping into southeastward was confirmed. This fault plane is not identified in JMA catalogue and relocation with HypoDD, though same observation data was used. And, from distribution of the 2010 northeast Chiba earthquake, it is revealed that reverse fault earthquakes are focused near plate boundary, whereas other earthquakes are located inside of subducting slab, deeper than plate boundary.

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-08 Room:302 Time:May 27 11:45-12:00

Initial development of the Matsushiro Earthquake Swarm and Influence of Tidal Strain on its Occurrence, the 2nd Report

Nobuo HAMADA[1*], Nosaka D.[2], Kobayashi M.[3], Yoshikawa K.[4], Ishigaki Y.[5], Tari S.[4]

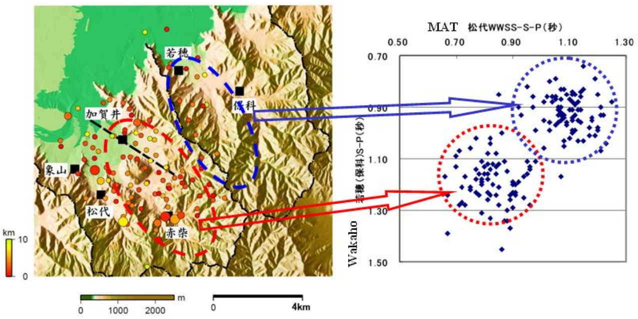
[1]Japan Nuclear Energy Safty Organization, [2]Matsushiro Seismological Observatory, [3]Osaka Disrict Meteorological Observatory, [4]Japan Meteorological Agency, [5]Yokohama Local Met. Observatory

Initial development of the Matsushiro earthquake swarm that started in early August of 1965 was investigated in detail by analyzing seismograms of Akashiba and Wakaho, temporarily operated stations of JMA, and we found that the initial stage of the swarm consists of two phases. In the initial stage, the swarm occurred in a small area north of the estimated Matsushiro earthquake fault and a month later in the next stage, a new activity occurred in a wider area south of the fault. To make the result more clear, we re-investigated WWSS-SP seismograms of Matsushiro(MAT) station. S-P times were picked from three component seismograms and averaged for each event to obtain a precision of about 1/20s. The new data and existing data suggested that a transition from the first phase to the second phase of the activity occurred rapidly in early September and S-P histograms of each station and comparison of them indicate that the northern area of the initial phase and the southern area of the second phase are defined and separated in each other clearly.

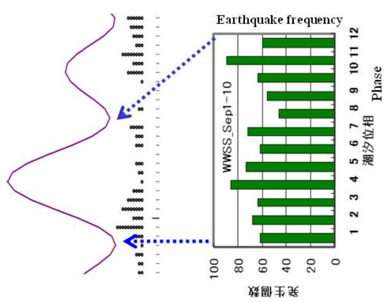
To relate the areas of the swarm in the initial stage to the geography, we studied hypocenters in October and November of 1965 after deployment of temporal seismic station network of the Earthquake Research Institute(ERI) and incorporated 6 stations data of JMA and ERI into hypocenter location. Preliminary location suggests that hypocenter distribution well correspond to the areas of initial development of the swarm.

We analyzed relation between tidal strain changes and earthquake swarm occurrence.

Among several tidal strain components, weak relation between volume, aerial tidal strains and occurrence of the swarm earthquake were found. In the first stage in 1965 August, earthquakes seemed to be occurring during tidal volume strain was in contraction stage and in the next stage in September, many earthquakes were occurring during tidal volume strain in dilatational phase. Volume strain may be related to the change in pore pressure and affected the occurrence of earthquake.



Hypocenters and comparison of S-P times for the initial stage of the Matsushiro Earthquake swarm (in the blue circles) and those in the second stage (in the red circles)



Volume tidal strain change and Earthquake Occurrence

Keywords: Matsushiro Earthquake Swarm, Tidal Strain, Pore Pressure

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-09 Room:302 Time:May 27 12:00-12:15

Earthquakes triggered by tides in Iwo-jima island, Japan

Yasuyuki Watanabe[1*], Masashi Kamogawa[1], Motoo Ukawa[2], Eisuke Fujita[2], Hideki Ueda[2]

[1]Dpt. of Phys., Tokyo Gakugei Univ., [2]Nat. Res. Inst. For Earth Sci. & Disaste

We investigate dynamic and tidal triggering of earthquakes in Iwo-jima, a south small volcanic island 1250 km away from Tokyo. After seismic waves of four far-distant huge earthquakes including 2004 Sumatra earthquake reached Iwo-jima, a local seismicity was activated. At the time of largest amplitude of arrival seismic waves, in particular, triggered earthquakes occurred in south - west area of Iwo-jima for all of huge earthquakes. From spectrum analysis of time-series of earthquake number per hour, M2 and K1 components of ocean tides significantly enhanced. In the presentation, we discuss the triggered mechanism.

Keywords: Seismicity, Triggering, Tide, Dynamic triggering

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-10 Room:302 Time:May 27 12:15-12:30

Hypocenter relocation of M7-class earthquakes and comparison with the interplate quasi-static slip in the Hyuga-nada

Yusuke Yamashita[1*], Hiroshi Shimizu[1], Kenji Uehira[1], Mikio Fujii[2]

[1]SEVO, Kyushu University, [2]Japan Meteorological Agency

In the Hyuga-nada region, the Philippine Sea Plate subducts northwestward beneath the Eurasian Plate an approximate rate of 5 ~ 7 cm/year, and M7-class interplate earthquakes have repeatedly occurred at decade years interval. We relocate the hypocenters of the main shock and aftershocks for the major interplate earthquakes which occurred in 1931 (Mjma7.1), 1941 (Mjma7.2), 1961 (Mjma7.0), and 1970 (Mjma6.7), and compare them with the quasi-static slip rate estimated by the analysis of small repeating earthquakes.

We used the smoked-paper records and the Seismological Bulletin of the Japan Meteorological Agency (JMA). All the hypocenters were relocated using S-P time instead of P or S arrival time for reducing the error caused by inaccuracies of the clock. We assumed that the hypocenters located on the plate boundary from *Uehira et al*. (2010). Theoretical S-P times were calculated by 3D ray trace with 3D velocity structure model.

The hypocenter relocation showed that the hypocenter of 1961 event locates at about 20km west of the hypocenter by JMA. The relocated hypocenter coincides with the area in which the interplate quasi-static slip rate is small [*Yamashita et al*., 2010]. This implies that the area corresponds to an asperity on the plate boundary, which is consistent with the results of stress tensor analysis by *Uehira* (2007).

Acknowledgement
We thank Dr. Yakiwara (NOEV, Kagoshima University) who provided 3D ray trace program. We also thank the members of the Fukuoka District Meteorological Observatory, Kagoshima, Miyazaki, Kumamoto, Oita, Saga, Shimonoseki Local Meteorological Observatory, and Nagasaki Marine Observatory for collecting the smoked-paper records of Hyuga-nada earthquakes.

Keywords: Hyuga-nada earthquake, Interplate quasi-static slip, Hypocenter relocation

Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS026-11 Room:302 Time:May 27 12:30-12:45

Remotely triggered seismicity in Yunnan, Southwestern China following the 2004 Mw9.3 Sumatra earthquake

Xinglin Lei[1*], Chaodi Xie[2], Bihong Fu[3]

[1]Geological Survey of Japan, AIST, [2]Department of Geophysics, Yunnan Univers, [3]Institute of Geology and Geophysics, Aca

Following the 2004 Mw9.3 Sumatra earthquake, seismicity increased sharply over a wide area of up to ~2,500 km away in Yunnan province, southwestern China. Raised seismicity lasts for approximately 14 days. During this period, more than 800 events having a magnitude of >=1.5 were observed, including at least 7 M4 class events and a M5.1 event. This is perhaps the most impressive example of remotely triggered seismicity yet observed. Major events were clustered at several sites that exhibit complex fault geometries, such as step-overs and junctures. We use statistic approaches including the Beta-statistics to examine the statistical significance of the seismic rate increases associated with the Sumatra mainshock and conclude that there is a reasonable probability that the raised seismicity was remotely triggered by the Sumatra earthquake.

Both rapid-onset dynamic triggering and delayed response were well established. During the first hour of event time (time from the origin time of the Sumatra earthquake), we can identify and locate at least 7 M1.5+ earthquakes. These events are embedded in the body waves and surface waves from the Sumatra earthquake. However, clear records at some stations are obtained by applying a high-pass filter to the original seismograms. The first identified event is a M4.6 earthquake occurred during the passage of the surface waves from the Sumatra earthquake. However, major clusters likely demonstrate significant delays in the onset of triggering seismicity, with the dominant energy releasing a few hours to a few days after the surface wave passed.

We use the epidemic-type aftershock sequence (ETAS) model to examine seismicity in the study in 2004 through 2005. Two major changing points and thus three phases (I through III) of activity pattern, are well determined. The second phase (II) corresponds to the period of seismic activity remotely triggered by the Sumatra earthquake. The ETAS models show great p0 (>30%) and small Alfa, which are 1.368, 0.804, and 1.328 for phases I, II, and III, respectively. Therefore, the triggered activities show earthquake swarm-like characteristics such as that indicated by the epidemic-type aftershock sequence (ETAS) modeling results (large percentage of random components and less magnitude dependence in Omori law type self triggering).

Multiple sources of evidence, including intensive hydrothermal activities, and low velocity and high Vp/Vs zones in the lower to middle crust suggests that magma/mantle-generated fluids have a role in the region. High fluid pressure in branched fault zones weakened the faults, making them sensitive to external disturbances and leading to fluid-driven seismicity.

Keywords: Remote triggering, ETAS, Fluid-driven seismicity, Yunnan, Sumatra Earthquake