Sat. Oct 31, 2020

ROOM D

Room D | Regular session | S14. Earthquake prediction and forecast

[S14]AM-1

chairperson:Takao Kumazawa(Earthquake Research Institute, University of Tokyo), chairperson:Jiancang Zhuang(The Institute of Statistical Mathematics, Research Organization of Information and Systems)
9:00 AM - 10:00 AM ROOM D

[S14-01] Long-term Probability of a Tohoku-Oki Earthquake along the Japan Trench
〇Masajiro Imoto[1], Nobuyuki Morikawa[1], Hiroyuki Fujiwara[1] （1.National Research Institute for Earth Science and Disaster Resilience）
9:00 AM - 9:15 AM

[S14-02] Foreshocks and earthquake hazard assessment in Japan mainland.
〇Hong Peng[1], James Jiro Mori[1] （1.Kyoto University）
9:15 AM - 9:30 AM

[S14-03] Predictability of earthquake swarms with consideration of central nagano swarm events in 2020
〇Kumazawa Takao[1], Yosihiko Ogata[2] （1.Earthquake Research Institute, The University of Tokyo, 2.The Institute of Statistical Mathematics）
9:30 AM - 9:45 AM

[S14-04] Incorporating focal mechanisms into the ETAS model
〇Jiancang Zhuang[1,2], Eri Maita[2] （1.The Institute of Statistical Mathematics, Research Organization of Information and Systems, 2.Department of Statistical Science, The Graduate University for Advanced Studies (SOKENDai)）
9:45 AM - 10:00 AM

Room D | Special session | S22. Geodyanamics of the Ryukyu arc

[S22]AM-2

chairperson:Shuichi Kodaira(JAMSTEC)
10:30 AM - 11:45 AM ROOM D

[S22-01] Overview of scientific drilling active backarc basin, Okinawa Trough: ongoing rifting of Eurasian continental margin
〇Makoto Otsubo[1] （1.Geological Survey of Japan）
10:30 AM - 10:45 AM

[S22-02] Vs structure of the shallow crust beneath ocean-bottom seismometers: south and north Okinawa trough
〇Ban-Yuan Kuo[1], Pei-Ru Jian[1], Pei-Ying Patty Lin[2], Ching-Ren Lin[1], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Chau-Chang Wang[5] （1.Institute of Earth Sciences, Academia Sinica, 2.National Taiwan Normal University, 3.JAMSTEC, 4.University of the Ryukyus, 5.NARLabs）
10:45 AM - 11:00 AM

[S22-03] Ambient noise tomography for northern Okinawa trough OBS array
〇Ting-Chun Lin[1], Kai-Xun Chen[1,2], Yuancheng Gung[1], Ban-Yuan Kuo[2], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Pei-Ying Patty Lin[5], Ching-Ren Lin[2], Chau-Chang Wang[6] （1.National Taiwan University, Department of Geosciences, 2.Academia Sinica, 3.JAMSTEC, 4.University of the Ryukyus, 5.National Taiwan Normal University, 6.National Applied Research Laboratories）
11:00 AM - 11:15 AM

[S22-04] [Invited] Contemporary deformation and slow slip events along the Ryukyu Islands clarified by GNSS observations
〇Takuya Nishimura[1], Shin'ichi Miyazaki[2], Takeshi Matsushima[3] （1.Disaster Prevention Research Institute, Kyoto University, 2.Graduate School of Science, Kyoto University, 3.Faculty of Science, Kyushu University）
11:15 AM - 11:45 AM

Room D | Special session | S22. Geodyanamics of the Ryukyu arc

[S22]PM-1

chairperson:Mamoru Nakamura(Ryukyu University)
1:00 PM - 2:15 PM ROOM D

[S22-05] Pattern of occurrence interval and spatial distribution of similar earthquakes in the northern Ryukyu Trench subduction zone obtained from ocean bottom seismic observation
〇Yukihiro Nakatani[1], Hiroshi Yakiwara[1], Shuichiro Hirano[1], Shigeru Nakao[1], Hiroki Miyamachi[2], Reiji Kobayashi[2], Yusuke Yamashita[3], Hiroshi Shimizu[4], Takeshi Matsushima[4], Kazunari Uchida[4], Kazuo Nakahigashi[5], Hideji Abe[7], Tomoaki Yamada[6], Masanao Shinohara[7] （1.NOEV, Kagoshima Univ., 2.Grad. School of Sci. and Eng., Kagoshima Univ., 3.DPRI, Kyoto Univ., 4.SEVO, Kyushu Univ., 5.Tokyo Univ. of Marine Sci. and Tech., 6.JMA, 7.ERI, UTokyo）

1:00 PM - 1:15 PM

[S22-06] Surface wave imaging of the lithosphere and asthenosphere system beneath north Okinawa Trough from NOT OBS array

〇PeiYing Patty Lin[1], Hsiu-Cheng Yeh[1], Chih-Ming Lin[1], Ban-Yuan Kuo[2], Shu-Huei Hung[3], Yuancheng Gung[3], Eh Tan[2], Kate Huihsuan Chen[1], Chau-Chang Wang[4,5], Ching-Ren Lin[2], Shuichi Kodaira[6], Yasushi Ishihara[6], Mamoru Nakamura[7] （1.Department of Earth Sciences, National Taiwan Normal University, 2.Academia Sinica, 3.National Taiwan University, 4.National Applied Research Laboratories, 5.National Sun Yat-sen University, 6.JAMSTEC , 7.University of the Ryukyus）

1:15 PM - 1:30 PM

[S22-07] Upper mantle P-wave velocity structure beneath the northern Ryukyu subduction zone from multiscale finite-frequency traveltime tomography

〇Shu-Huei Hung[1], Ban-Yuan Kuo[2], Pei-Ying Patty Lin[1], Yuancheng Gung[1], Eh Tan[2], Huihsuan Chen[3], Chau-Chang Wang[4], Shuichi Kodaira[5], Yasushi Ishihara[5], Mamoru Nakamura[6], Ching-Ren Lin[2] （1.Department of Geosciences, National Taiwan University, 2.Academia Sinica, 3.National Taiwan Normal University, 4.National Applied Research Laboratories, 5.JAMSTEC, 6.University of the Ryukyus）

1:30 PM - 1:45 PM

[S22-08] [Invited] Active and passive seismic investigations in the Ryukyu Trench and the Okinawa Trough: A review of 7-year achievements by JAMSTEC

〇Ryuta Arai[1], Shuichi Kodaira[1], Tsutomu Takahashi[1], Ayako Nakanishi[1], Yojiro Yamamoto[1], Yuka Kaiho[1], Yasushi Ishihara[1], Seiichi Miura[1], Yoshiyuki Kaneda[1,2] （1.JAMSTEC, 2.Kagawa University）

1:45 PM - 2:15 PM

Room D | Regular session | S14. Earthquake prediction and forecast

[S14]AM-1

chairperson:Takao Kumazawa(Earthquake Research Institute, University of Tokyo), chairperson:Jiancang Zhuang(The Institute of Statistical Mathematics, Research Organization of Information and Systems)
Sat. Oct 31, 2020 9:00 AM - 10:00 AM ROOM D

[S14-01] Long-term Probability of a Tohoku-Oki Earthquake along the Japan Trench

〇Masajiro Imoto[1], Nobuyuki Morikawa[1], Hiroyuki Fujiwara[1] （1.National Research Institute for Earth Science and Disaster Resilience）

9:00 AM - 9:15 AM

[S14-02] Foreshocks and earthquake hazard assessment in Japan mainland.

〇Hong Peng[1], James Jiro Mori[1] （1.Kyoto University）

9:15 AM - 9:30 AM

[S14-03] Predictability of earthquake swarms with consideration of central nagano swarm events in 2020

〇Kumazawa Takao[1], Yosihiko Ogata[2] （1.Earthquake Research Institute, The University of Tokyo, 2.The Institute of Statistical Mathematics）

9:30 AM - 9:45 AM

[S14-04] Incorporating focal mechanisms into the ETAS model

〇Jiancang Zhuang[1,2], Eri Maita[2] （1.The Institute of Statistical Mathematics, Research Organization of Information and Systems, 2.Department of Statistical Science, The Graduate University for Advanced Studies (SOKENDai)）

9:45 AM - 10:00 AM

Long-term Probability of a Tohoku-Oki Earthquake along the Japan Trench

*Masajiro Imoto[1], Nobuyuki Morikawa[1], Hiroyuki Fujiwara[1]

1. National Research Institute for Earth Science and Disaster Resilience

東北地方太平洋沖を震源とする超巨大地震（東北地方太平洋沖型）について、政府地震調査委員会は、繰り返し発生する地震に対するBrownian Passage Time 分布(BPT分布)モデルを用いて、今後50年における地震発生の確率を評価している。長期評価報告書(平成31.2.26)によると、仙台平野で採取された５層の津波堆積物に基づき、５回の地震発生が確認されている。最初の２回の発生時期には、200年程度の不確定性がある。第３番の地震は869年の貞観地震、第５番は2011年の東北地方太平洋沖地震であるが。第４番については２つの歴史地震（1454年享徳地震、1611年慶長三陸地震）が候補とされている。報告書では、発生年が不確定な３個の地震については乱数により発生年を仮定し、再現し得る多数の時系列ついてBPTパラメータを最尤法で求め、その出現頻度を基に最適解を求めている。

地震発生年の不確定性に関しては、別の報告書「長期的な地震発生確率の評価手法について」（評価手法、平成13年6月）で、モデルパラメータ推定のための尤度関数が多重積分の式で与えられている（Ogata,1999 JGR）。この手法の適用対象と見られる地震として、東北地方太平洋沖型の他に、相模トラフ沿いのM8クラス地震（関東M8：調査委員会報告書，平成26年4月）と、千島海溝沿いの超巨大地震（17世紀型：平成29年12月）が挙げられる。このうち関東M8の評価では、評価手法に記載された多重積分と同等なモンテカルロ法（Parsons,2008）によって最尤パラメータが推定されている。その後の報告書（17世紀型,東北地方太平洋沖型）ではこれとは異なる方法（上記）が採用されている。ここでは、評価手法記載の方法によって、BPTモデルパラメータの最尤解を求め、報告書の値と比較する。

モデルパラメータの最尤解を推定する際に、第３番目の貞観地震を境に計算を分ける。第１番～第３番では、評価手法の方法に従い尤度を数値積分により求める。第１番と第２番の地震発生年が、積分変数となる。尤度は、平均発生間隔300年～900年、ばらつきパラメータ　0.1～2.0の範囲でデタラメに選んだ10,000点において計算する。また、後半の第３番～第５番については、重み付き尤度法に従って、２通りの第４番発生年に対応する２個の尤度の相乗平均を尤度とする。後半については、この期間における最尤値を基準として、先に選んだ10,000点における尤度の相対値を求める。この相対値と第１番～第３番の数値積分との積として、第１番～第５番における尤度を得る。

検算として、第１番～第３番の数値積分に代えてParsons(2008)によるモンテカルロ法を実施する。計算時間短縮のため時間軸を反転し、第３番地震から遡ることとする。パラメータの各点において5000時系列を生起し、不確定期間に合致する時系列を計数する。合致時系列数は第１番～第３番の積分値とよい比例関係を示す。尤度は　平均間隔560年ばらつき0.2で最大となる。全期間に対する尤度の分布を図に示す。

報告書(平成31.2.26)の図４-10と比較すると、違いは次の通りである。報告書では、平均発生間隔は全て約550年から約600年の50年間に収まっている。今回の結果では、800の等高線がほぼ同じ範囲になっている。尤度400の等高線では、約500年から670年の範囲に広がっている。報告書の方法では再現可能な時系列の平均間隔が最尤解となるため、第１地震の不確定性200年が50年（４分の１，地震間隔数の逆数）に縮小したと推察できる。これに対して、評価手法の方法では、任意のパラメータ値に対して尤度が計算される。また、ばらつきパラメータについては、図4-10では0.22付近に頻度の不連続が見られる。第４の地震が1611年慶長三陸地震の場合には、ばらつきパラメータが0.22以上となるため不連続が生じたと推察される。

平均的な発生確率は、各パラメータに対する発生確率の加重（通常は尤度）平均で表される。図4-10と今回の

結果を比べると、ばらつきパラメータ0.22以下や平均間隔約550年以下あるいは約600年以上のパラメータに対する確率の寄与が、報告書の方法では少ないことになる。今回の例では最新地震(2011年)からの経過年数が短いため平均的確率値に差は生じていないが、経過年数の長い地震で有意な差が生じることもあり得る。手法の妥当性について検討が必要である。

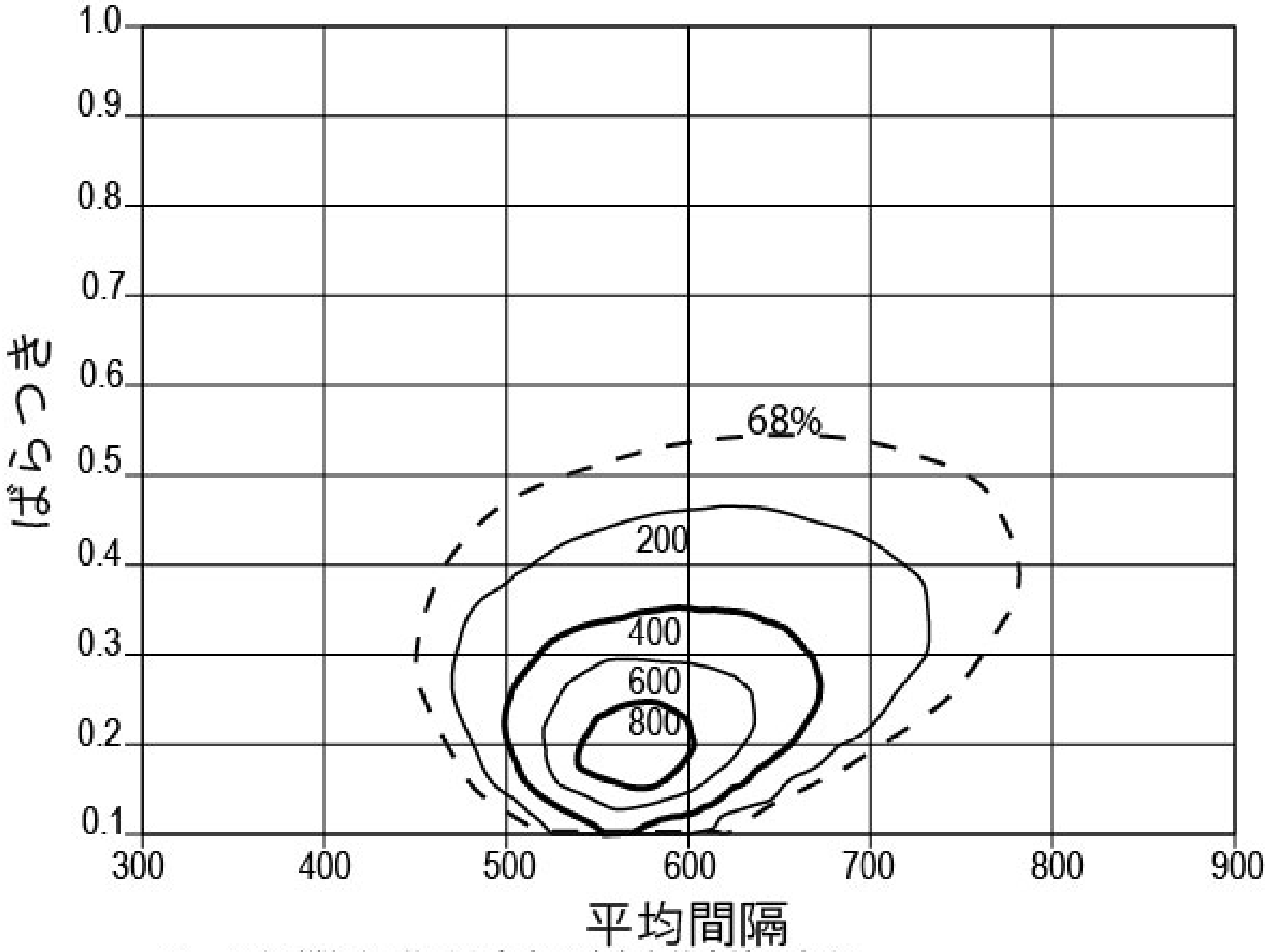


図　４地震間隔に基づく尤度の分布を等高線で表す。
破線は信頼区間 68%で推定されるパラメータ範囲を示す。

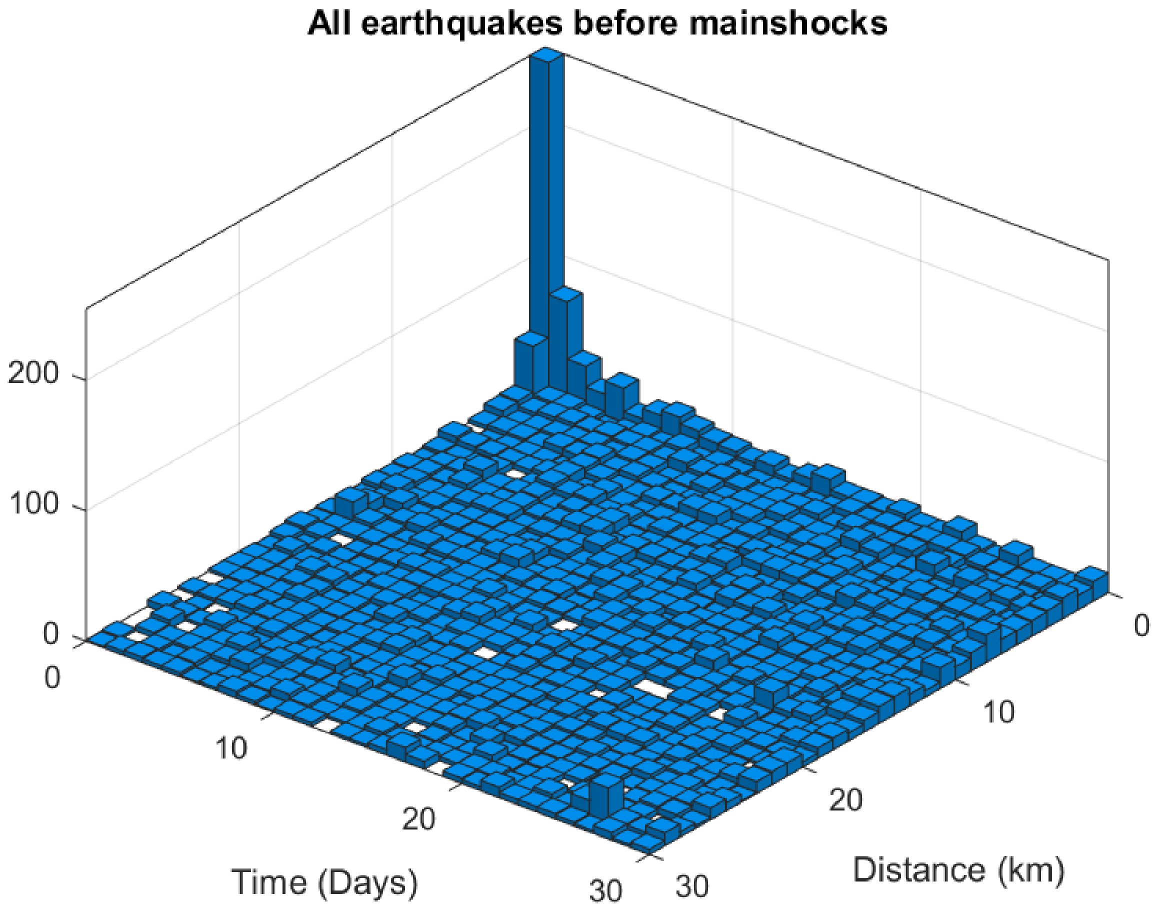
Foreshocks and earthquake hazard assessment in Japan mainland.

*Hong Peng[1], James Jiro Mori[1]

1. Kyoto University

In the past, studies of foreshocks have estimated the rate of foreshock occurrence before moderate and large earthquakes in high seismicity areas such as California. Those studies also show that it is possible to calculate the significant probability that a larger earthquake follow a specific event. In our study, we use the earthquakes recorded on land in the Japan Meteorological Agency catalogue from 2004 to 2019 to study foreshock. We looked at the temporal and spatial distributions of pairs of earthquakes where a smaller earthquake is followed by a larger earthquake. There is a clear peak for pairs of events that are located with 5 days and 2 km of each other. Therefore our definition of a foreshock is an event that is followed by a larger event within 5 days and located within 2 km. In this analysis, we removed aftershocks and sequences of earthquake swarms.

According to our results, about 40% of mainshocks (M >= 3.0) have foreshocks. This is consistent with previous studies that foreshocks could be a useful tool for the short-term earthquake hazard assessment. Also, wwe also estimated that the average probability that an earthquake will be followed by an earthquake of large magnitude is ~10%.


All earthquakes before mainshocks
200
100
0
0
10
20
30
Time (Days)
0
10
20
30
Distance (km)

Predictability of earthquake swarms with consideration of central nagano swarm events in 2020

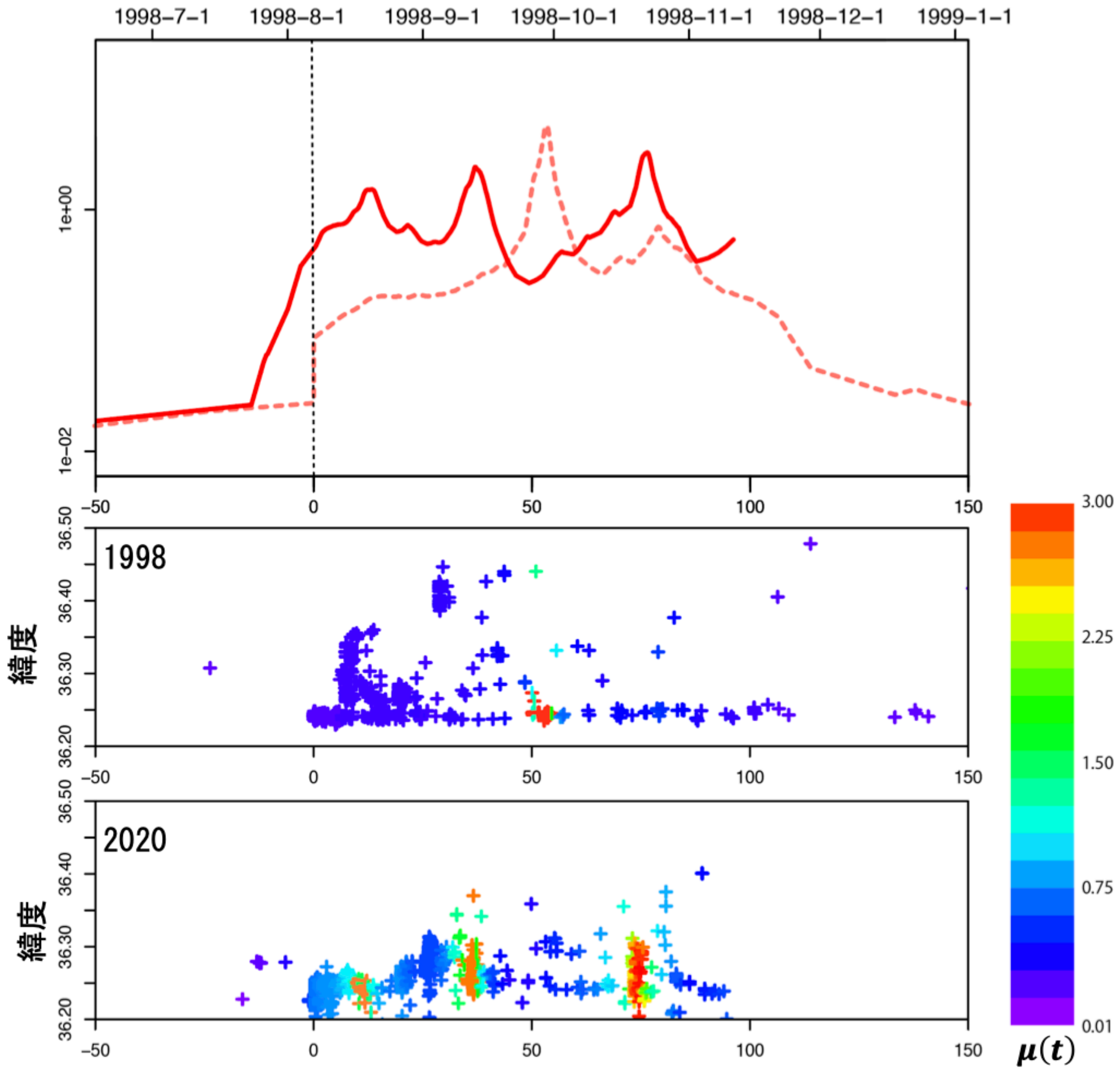
*Kumazawa Takao[1], Yosihiko Ogata[2]

1. Earthquake Research Institute, The University of Tokyo, 2. The Institute of Statistical Mathematics

ゆっくりと断層が滑るスロースリップや、火山活動時の流体貫入などによる断層の弱化はしばしば群発地震活動を誘発する. このタイプの地震活動は、地震の予測に一般的に使用されるETASモデルが想定する、時間的に先行する地震による誘発の連鎖とは異なる因果関係で発生するため、地震カタログのみからの予測が困難であることが知られている. しかしながら、誘発源である地殻内現象の測地学的データを用いることで、短期的な予測が可能になると考えられる. 鍵となるのは単位時間あたりの地震の期待発生数(強度)のうち、他の地震と独立な成分：常時地震活動(background seismicity)、を感度良く推定することにあり、我々の研究ではこれをベイズ法による非定常ETASモデル(Kumazawa and Ogata, 2013)で実践する。さらに非定常ETASモデルを今年4月から続く長野県中部の群発地震に適用し、常時地震活動の時間変化とそこから得られる特徴について議論する。

常時地震活動の比較 非定常ETAS: $\lambda_\theta(t|H_t) = \mu(t) + \sum_{\{i:S\le t_i<t\}} K_0(t) e^{\alpha(M_i - M_c)}/(t - t_i + c)^p$

$\lambda_\theta(t|H_t)$, $\mu(t)$, $K_0(t)$**の単位は地震数/日**



推定期間はそれぞれ1998年8月7日の群発開始(M2.2)と2020年4月23日のM5.5を時刻0と置いてその前50日、その後150日を対象期間とした。
2020年の群発は7月24日までのデータを含む。領域は経度(137.55, 137.72), 緯度(36.20, 36.50).

1998年の群発は約４ヶ月後に以前のレベルに戻った。
注意点として、群発初期のバックグラウンドは過小評価している可能性がある。t=50 辺りのバックグラウンドの上昇は南部クラスターのごく一部に比較的小さな地震が集中して発生したことに因る。

2020年の群発は4月23日のM5.5をt＝０としたが、先行する地震があるのでバックグラウンドもt=0以前から上昇する. 検知率は1998年と比べて高いので、安定した推定結果と思われる。1998年と同規模と仮定すればそろそろ収束に向かう時期だが、もう少しデータを加えて様子を見る必要があると思われる。

Incorporating focal mechanisms into the ETAS model

*Jiancang Zhuang[1,2], Eri Maita[2]

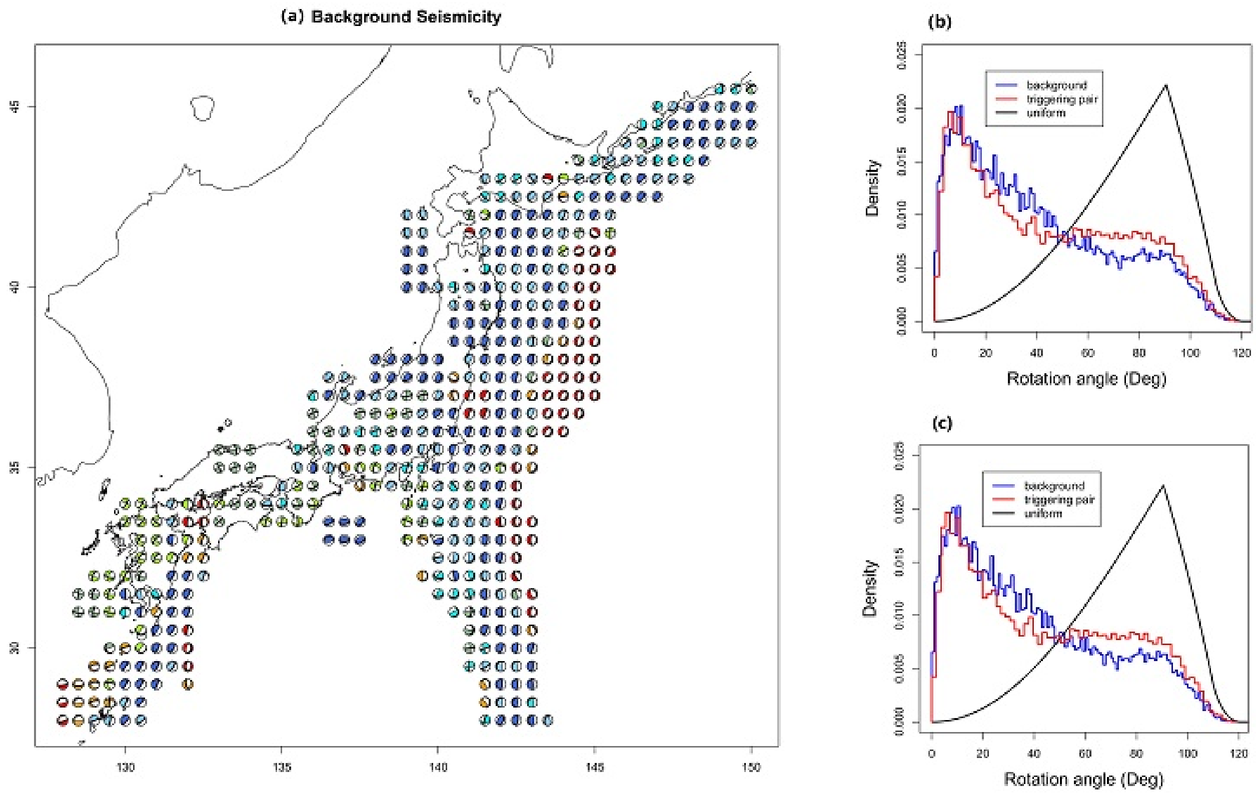
1. The Institute of Statistical Mathematics, Research Organization of Information and Systems, 2. Department of Statistical Science, The Graduate University for Advanced Studies (SOKENDai)

This study tries to find the probability distributions of focal mechanisms in background seismicity and earthquake clusters in Japan by analyzing F-net data. To describe the probability distribution, each focal mechanism is discomposed as the result of a rotation about a particular pole starting from a reference focal mechanism. In this study, DC4 symmetry is considered, i.e., either nodal-plane can be the fault plane and the two sides of the fault plane are distinguishable. To separate the background and clustering seismicity, we fit the space-time ETAS model (e.g., Zhuang, 2011, EPS) to the earthquakes with magnitude 4.2+ from 1997 to 2017 in the F-net catalog, and use the stochastic declustering method to estimate the background probabilities that each event is a background event and the triggered probabilities that each event is triggered by other events.
Figure caption:

For the background events, the reference focal mechanism is taken as the average focal mechanism in each area, calculated by the method in Kagan and Jackson (2014, GJI). The rotation angles between a background event and the mean focal mechanisms at (x, y) is reconstructed by histogram of rotation angles between each earthquake and the local mean focal mechanism, weighted by its background probability estimated from the ETAS model. For a triggered event, the reference focal mechanism naturally takes the value of the focal mechanism of the event which triggers it. The rotation angles between the parent event and its direct offspring are also reconstructed by histogram of rotation angles between each triggering pair, weighted by the probability that the 2nd event is triggered by the first event in the pair. We also find that the rotation poles are almost uniformly distributed.

We then plug the reconstructed focal mechanisms distribution into the space-time ETAS model and apply it to the F-net data. The results show that focal mechanism plays an important role in earthquake triggering and incorporation with focal mechanism greatly improves model fitting.

Fig. 1 (a) shows the mean focal mechanisms of background seismicity in Japan, (b) gives the reconstructed probability density functions of rotation angles for focal mechanisms in the background seismicity and triggered seismicity, and (c) gives the cumulative distribution functions corresponding to the pdfs in (b).


(a) Background Seismicity
45
40
35
30
130
135
140
145
150
(b)
Density
0.000
0.005
0.010
0.015
0.020
0.025
0
20
40
60
80
100
120
Rotation angle (Deg)
background
triggering pair
uniform
(c)
Density
0.000
0.005
0.010
0.015
0.020
0.025
0
20
40
60
80
100
120
Rotation angle (Deg)
background
triggering pair
uniform

Room D | Special session | S22. Geodyanamics of the Ryukyu arc

[S22]AM-2

chairperson:Shuichi Kodaira(JAMSTEC)

Sat. Oct 31, 2020 10:30 AM - 11:45 AM ROOM D

[S22-01] Overview of scientific drilling active backarc basin, Okinawa Trough: ongoing rifting of Eurasian continental margin

〇Makoto Otsubo[1] （1.Geological Survey of Japan）

10:30 AM - 10:45 AM

[S22-02] Vs structure of the shallow crust beneath ocean-bottom seismometers: south and north Okinawa trough

〇Ban-Yuan Kuo[1], Pei-Ru Jian[1], Pei-Ying Patty Lin[2], Ching-Ren Lin[1], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Chau-Chang Wang[5] （1.Institute of Earth Sciences, Academia Sinica, 2.National Taiwan Normal University, 3.JAMSTEC, 4.University of the Ryukyus, 5.NARLabs）

10:45 AM - 11:00 AM

[S22-03] Ambient noise tomography for northern Okinawa trough OBS array

〇Ting-Chun Lin[1], Kai-Xun Chen[1,2], Yuancheng Gung[1], Ban-Yuan Kuo[2], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Pei-Ying Patty Lin[5], Ching-Ren Lin[2], Chau-Chang Wang[6] （1.National Taiwan University, Department of Geosciences, 2.Academia Sinica, 3.JAMSTEC, 4.University of the Ryukyus, 5.National Taiwan Normal University, 6.National Applied Research Laboratories）

11:00 AM - 11:15 AM

[S22-04] [Invited] Contemporary deformation and slow slip events along the Ryukyu Islands clarified by GNSS observations

〇Takuya Nishimura[1], Shin'ichi Miyazaki[2], Takeshi Matsushima[3] （1.Disaster Prevention Research Institute, Kyoto University, 2.Graduate School of Science, Kyoto University, 3.Faculty of Science, Kyushu University）

11:15 AM - 11:45 AM

Overview of scientific drilling active backarc basin, Okinawa Trough: ongoing rifting of Eurasian continental margin

*Makoto Otsubo[1]

1. Geological Survey of Japan

We introduce the outline of scientific drilling for the Okinawa Trough, active backarc basin. Active backarc basins are unique tectonic features which divide the margin of continents, generate complex subduction geometries, and host a large number of hydrothermal systems that harbour unique mineralization and diverse biological communities. The mechanisms controlling the initiation and evolution of backarc basins has been a long-standing question in global tectonics. Our targets are to perform coring, logging, and monitoring at the Okinawa Trough backarc basin, the Ryukyu arc. The Okinawa Trough is a ~1500-km long continental rift in the East China Sea parallel to and behind the Ryukyu Arc. The Okinawa Trough, together with Bransfield Strait which is in a challenging Antarctic environment and therefore we do not think it is prospective target for a scientific drilling, is the only active and accessible continental backarc basin on earth which has not produced oceanic crust via seafloor spreading yet. Here we propose a new hypothesis on the driving force of the backarc opening: Backarc spreading accelerates with fluids and heat-induced weakening and strain concentration in the rift zone. We propose 3 shallow (200–700 m below the seafloor) riserless boreholes in the southern part of the Okinawa Trough. The drilling of these boreholes aims to recover sediments, volcanic rocks, and pore fluids, collect geophysical logs, and make downhole measurements. The objectives of the riserless program are two-fold: (1) Examine the fluid circulation process in shallow crust by documenting and analysing the physical, hydrogeological and chemical properties, lithology, geometry, microstructure, and thermal state of the fault; and (2) Observe volcanics that are extruded before oceanic basalts are exposed by characterizing the entire sedimentary and volcanic facies under the trough axis (Yaeyama Graben) including the top of a potentially basaltic volcanic intrusion observed in the seismic surveys. This proposal is the first milestone of our future drilling project which ultimately aims to core and monitor in both of the seismogenic rifts zone in the Okinawa Trough and the onland Ryukyu arc.

Vs structure of the shallow crust beneath ocean-bottom seismometers: south and north Okinawa trough

*Ban-Yuan Kuo[1], Pei-Ru Jian[1], Pei-Ying Patty Lin[2], Ching-Ren Lin[1], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Chau-Chang Wang[5]

1. Institute of Earth Sciences, Academia Sinica, 2. National Taiwan Normal University, 3. JAMSTEC, 4. University of the Ryukyus, 5. NARLabs

We employ a P-wave polarization method to estimate the Vs of the shallow crust beneath ocean-bottom seismometer (OBS) arrays in Okinawa trough. In comparison, we applied this method to F-net in the Tohoku region, Japan. We found that the seafloor beneath OBSs is characterized by Vs of hundreds of m/s, while Vs of the shallow crust of Tohoku is typically 2-4 km/s with the about 1 km/s at volcano sites. The OBSs along the Okinawa trough were probably deployed on the very soft oceanic crust first layer composed of young, uncompact sediment. The observed Ps following the P phase attests to this hypothesis. We are in the process of extending this research to OBSs on old seafloor of the Pacific basin.

Ambient noise tomography for northern Okinawa trough OBS array

*Ting-Chun Lin[1], Kai-Xun Chen[1,2], Yuancheng Gung[1], Ban-Yuan Kuo[2], Yasushi Ishihara[3], Shuichi Kodaira[3], Mamoru Nakamura[4], Pei-Ying Patty Lin[5], Ching-Ren Lin[2], Chau-Chang Wang[6]

1. National Taiwan University, Department of Geosciences, 2. Academia Sinica, 3. JAMSTEC, 4. University of the Ryukyus, 5. National Taiwan Normal University, 6. National Applied Research Laboratories

From September 2018 to June 2019, IES, TORI, and JAMSTEC deployed broadband OBSs in the north Okinawa trough and its neighboring sea (NOT). Data from OBS vertical component combined with that from F-net stations and five temporary stations are suitable to ambient noise study. We perform ambient noise tomography using these array data to map the upper crust to shallow mantle structures of this part of the Ryukyu subduction zone. Cross-correlation functions were calculated and phase velocities of 5-30 s were measured, followed by a one-step, wavelet-based multiscale inversion for 3-D models of both Vs and its azimuthal anisotropy. Preliminary results show correlation between the resolved azimuthal anisotropy and the measured shear-wave splitting from local slab events. We are especially interested in whether medium-sized melt mush zone in the crust can be identified beneath the OT as evidence for late stage of continental rifting and early stage of seafloor spreading.

[Invited] Contemporary deformation and slow slip events along the Ryukyu Islands clarified by GNSS observations

*Takuya Nishimura[1], Shin'ichi Miyazaki[2], Takeshi Matsushima[3]

1. Disaster Prevention Research Institute, Kyoto University, 2. Graduate School of Science, Kyoto University, 3. Faculty of Science, Kyushu University

The Ryukyu Islands lie on a 1200-km-long island arc from Kyushu to Taiwan. Contemporary deformation of the Ryukyu Islands is characterized by subduction of the oceanic plate and active backarc spreading. The Philippine Sea plate subducts from the Ryukyu Trench beneath the islands. Numerous earthquakes and slow slip events (SSEs) occur along the subduction plate interface. Active backarc spreading along the Okinawa Trough also causes many shallow earthquakes in the island arc. The permanent GNSS observation network named GEONET was started in the 1990’s and it has greatly contributed our understanding on ongoing deformation due to these tectonic processes. Recently, our group has been constructed additional 15 GNSS stations in the islands, particularly the Yaeyama Islands, southernmost parts of the Ryukyu Islands. In this presentation, we review the previous geodetic studies on the contemporary deformation and SSEs as well as our new results of recent GNSS observations.

The secular GNSS velocity shows rapid backarc spreading along the Okinawa Trough and the spreading rate increases toward south (e.g., S. Nishimura, 2004; Nakamura, 2004; Watanabe and Tabei, 2004). Internal deformation of the island arc is rather small and modeled by rigid block rotation of three or four independent tectonic blocks. No significant contraction along the plate convergence was found, which suggests low coupling on the subduction plate interface. However, land geodetic data cannot resolve offshore coupling near the trench (e.g., Watanabe and Tabei, 2004) On the other hand, significant expansion along the arc was revealed by Nakamura (2004).

It is probable that SSEs as well as earthquakes accommodate a significant part of relative plate motion along the Ryukyu Trench. T. Nishimura (2014) conducted a systematic search of short-term SSEs using GNSS data and found 223 possible SSEs for 16 years. Detected SSEs distributes from the trench to the island arc with a depth range between 10 and 60 km shows highly heterogeneous along the trench. The most distinctive activity is bi-annual M_w~6.6 SSEs in the Yaeyama Islands (Heki and Kataoka, 2008; Tu and Heki, 2017; Kano et al., 2018). The cluster of SSEs locates southeast off southern Okinawajima, east off Kikaijima, and east of Tanegashima. Correlations between SSEs and other slow and regular earthquakes (e.g., low-frequency earthquakes, very-low-frequency earthquakes, and earthquake tremors) have been also found (Nakamura, 2015; Nakamura, 2017) but their relation is not simple and unlike the episodic tremor and slip events along Nankai Trough.

We estimated secular velocity at continuous stations including new stations from August 2017 to July 2020 in and around the Ryukyu Islands (Figure). This new velocity confirmed previous studies and gave us some additional insights on ongoing deformation. Expanded internal deformation in directions of both along and perpendicular to the trench are dominant in the Yaeyama Islands and Okinawajima but contraction along the relative plate motion is observed in a part of the Yaeyama Islands. Southeastward velocity of Io-torishima suggests volcanic inflation of the island.

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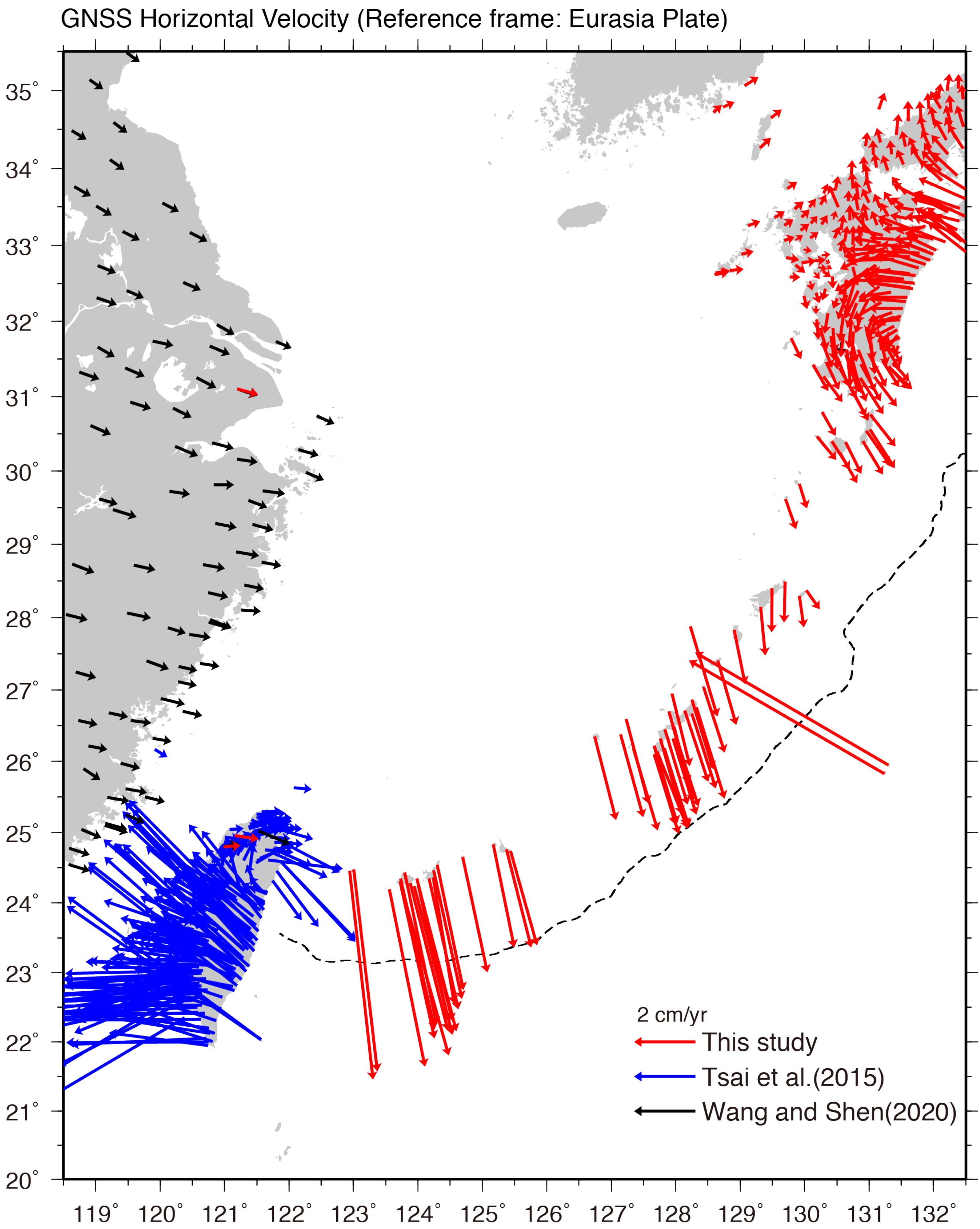

Room D | Special session | S22. Geodyanamics of the Ryukyu arc

[S22]PM-1

chairperson:Mamoru Nakamura(Ryukyu University)

Sat. Oct 31, 2020 1:00 PM - 2:15 PM ROOM D

[S22-05] Pattern of occurrence interval and spatial distribution of similar earthquakes in the northern Ryukyu Trench subduction zone obtained from ocean bottom seismic observation

〇Yukihiro Nakatani[1], Hiroshi Yakiwara[1], Shuichiro Hirano[1], Shigeru Nakao[1], Hiroki Miyamachi[2], Reiji Kobayashi[2], Yusuke Yamashita[3], Hiroshi Shimizu[4], Takeshi Matsushima[4], Kazunari Uchida[4], Kazuo Nakahigashi[5], Hideji Abe[7], Tomoaki Yamada[6], Masanao Shinohara[7] （1.NOEV, Kagoshima Univ., 2.Grad. School of Sci. and Eng., Kagoshima Univ., 3.DPRI, Kyoto Univ., 4.SEVO, Kyushu Univ., 5.Tokyo Univ. of Marine Sci. and Tech., 6.JMA, 7.ERI, UTokyo）

1:00 PM - 1:15 PM

[S22-06] Surface wave imaging of the lithosphere and asthenosphere system beneath north Okinawa Trough from NOT OBS array

〇PeiYing Patty Lin[1], Hsiu-Cheng Yeh[1], Chih-Ming Lin[1], Ban-Yuan Kuo[2], Shu-Huei Hung[3], Yuancheng Gung[3], Eh Tan[2], Kate Huihsuan Chen[1], Chau-Chang Wang[4,5], Ching-Ren Lin[2], Shuichi Kodaira[6], Yasushi Ishihara[6], Mamoru Nakamura[7] （1.Department of Earth Sciences, National Taiwan Normal University, 2.Academia Sinica, 3.National Taiwan University, 4.National Applied Research Laboratories, 5.National Sun Yat-sen University, 6.JAMSTEC , 7.University of the Ryukyus）

1:15 PM - 1:30 PM

[S22-07] Upper mantle P-wave velocity structure beneath the northern Ryukyu subduction zone from multiscale finite-frequency traveltime tomography

〇Shu-Huei Hung[1], Ban-Yuan Kuo[2], Pei-Ying Patty Lin[1], Yuancheng Gung[1], Eh Tan[2], Huihsuan Chen[3], Chau-Chang Wang[4], Shuichi Kodaira[5], Yasushi Ishihara[5], Mamoru Nakamura[6], Ching-Ren Lin[2] （1.Department of Geosciences, National Taiwan University, 2.Academia Sinica, 3.National Taiwan Normal University, 4.National Applied Research Laboratories, 5.JAMSTEC, 6.University of the Ryukyus）

1:30 PM - 1:45 PM

[S22-08] [Invited] Active and passive seismic investigations in the Ryukyu Trench and the Okinawa Trough: A review of 7-year achievements by JAMSTEC

〇Ryuta Arai[1], Shuichi Kodaira[1], Tsutomu Takahashi[1], Ayako Nakanishi[1], Yojiro Yamamoto[1], Yuka Kaiho[1], Yasushi Ishihara[1], Seiichi Miura[1], Yoshiyuki Kaneda[1,2] （1.JAMSTEC, 2.Kagawa University）

1:45 PM - 2:15 PM

Pattern of occurrence interval and spatial distribution of similar earthquakes in the northern Ryukyu Trench subduction zone obtained from ocean bottom seismic observation

*Yukihiro Nakatani[1], Hiroshi Yakiwara[1], Shuichiro Hirano[1], Shigeru Nakao[1], Hiroki Miyamachi[2], Reiji Kobayashi[2], Yusuke Yamashita[3], Hiroshi Shimizu[4], Takeshi Matsushima[4], Kazunari Uchida[4], Kazuo Nakahigashi[5], Hideji Abe[7], Tomoaki Yamada[6], Masanao Shinohara[7]

1. NOEV, Kagoshima Univ., 2. Grad. School of Sci. and Eng., Kagoshima Univ., 3. DPRI, Kyoto Univ., 4. SEVO, Kyushu Univ., 5. Tokyo Univ. of Marine Sci. and Tech., 6. JMA, 7. ERI, UTokyo

南西諸島海溝のプレート境界面上では，プレート沈み込みに伴う通常の地震に加え，低周波微動や短期的SSEといったスロー地震も発生しており，他の沈み込み帯と同様に両者の空間分布が議論されている．これまで，海溝軸から100 km以上離れた島嶼部が主な観測網であったため，隣接する南海トラフと比べても，地震とスロー地震の対応関係やプレート境界におけるすべり特性の理解は遅れていたが，近年において短期～中長期的な海底地震観測網の展開が進展しつつある．
本研究チームは，トカラ列島東方海域において長期収録型海底地震計を用いた繰り返し海底地震観測を実施した．2014年に3台体制で開始した本観測は，2015年以降，6台の自己浮上型海底地震計を約1年周期で回収・設置を繰り返しながら継続し，2019年11月の回収をもって第一次観測を完了した．観測点間隔が約40–60 kmとやや疎であるが，観測空白域であった当該海域において，約5ヶ年にわたる準定常的な観測網を構築したのが特徴である．
本研究では，2016年7月～2018年3月の上記観測データを用いて，プレート境界周辺で発生する波形のよく似た地震（相似地震）を，その発生間隔に応じて分類し，活動様式を議論した．相似地震の検出にはMatched-Filter法を採用し，6台の海底地震計および島嶼観測点の3成分連続波形データに適用した．テンプレート地震には，鹿児島大学南西島弧地震火山観測所が決定したマグニチュード3以上の地震を選択し，海底地震観測点の検測データを統合して震源再決定した．相似地震群は，発生間隔から次の3つの活動様式に分類された．群発地震型，小繰り返し地震型，そして両者の混合型である．本講演では，検出イベントとテンプレート地震の相対震源位置を評価した上で，微動分布や構造との空間関係について議論する．
2019年4月からは観測点間隔20 km（計8台）のより稠密な第二次海底地震観測を開始し，2020年8月に一回目の回収・再設置を完了した．本講演では当該観測計画についても報告する．

謝辞：観測航海は，長崎大学水産学部附属練習船長崎丸の教育関係共同利用に基づき実施されました．本研究は文部科学省による「災害の軽減に貢献するための地震火山観測研究計画」および「同計画（第2次）」の支援を受けました．また，東京大学地震研究所共同利用の援助を受けました．記して感謝いたします．

Surface wave imaging of the lithosphere and asthenosphere system beneath north Okinawa Trough from NOT OBS array

*PeiYing Patty Lin[1], Hsiu-Cheng Yeh[1], Chih-Ming Lin[1], Ban-Yuan Kuo[2], Shu-Huei Hung[3], Yuancheng Gung[3], Eh Tan[2], Kate Huihsuan Chen[1], Chau-Chang Wang[4,5], Ching-Ren Lin[2], Shuichi Kodaira[6], Yasushi Ishihara[6], Mamoru Nakamura[7]

1. Department of Earth Sciences, National Taiwan Normal University, 2. Academia Sinica, 3. National Taiwan University, 4. National Applied Research Laboratories, 5. National Sun Yat-sen University, 6. JAMSTEC , 7. University of the Ryukyus

The NOT experiment is an ocean bottom seismic experiment conducted at the north part of the Okinawa Trough as a collaboration between Taiwan and Japan. The NOT experiment is designed to image the structure of the Ryukyu subduction system which consists of trench–arc–backarc extending from Japan to Taiwan. The Okinawa Trough (OT), the backarc basin in the Ryukyu subduction system, is unique due to its extensive active rifting. Here we present surface wave analysis data from the ˜21 broadband ocean bottom seismograms and 3 land-stations from the F-net network of Japan. With the passive seismic imaging using this seismic array with the aperture ˜260 km, we can have local constraints on the seismic model in the lithosphere and asthenosphere system. Noise levels in vertical components of the most OBS sit within the global reference new high- and low- noise models with significant tilt and compliance noises contaminations. Tilt and compliance noises arise from instrument tilting under bottom current flow due to coupling problems and seafloor deformation caused by the infragravity wave respectively. We first characterize the temporal variations of tilt and compliance noises for each station. We then remove tilt and compliances noises from vertical recordings sequentially to retrieve true ground motions due to the structural properties. We utilize an intra-array cross-correlation analysis to measure Rayleigh-wave phase velocities for the teleseismic events with noises corrected vertical data. Phase velocity maps from the shorter period (< 32s sec) show low velocities beneath the volcanic arc. In the mid-period (40- 70s), the low phase velocity anomaly is seen beneath Okinawa Trough. We plan to show regional dispersion patterns beneath the backarc basin and volcanic arc to understand the seismic structure within the lithosphere and asthenosphere system.

Keywords: Ryukyu subduction, broad-band ocean-bottom seismograph (BBOBS), seismic noise, compliance and tilt corrections, Rayleigh wave phase velocity

Upper mantle P-wave velocity structure beneath the northern Ryukyu subduction zone from multiscale finite-frequency traveltime tomography

*Shu-Huei Hung[1], Ban-Yuan Kuo[2], Pei-Ying Patty Lin[1], Yuancheng Gung[1], Eh Tan[2], Huihsuan Chen[3], Chau-Chang Wang[4], Shuichi Kodaira[5], Yasushi Ishihara[5], Mamoru Nakamura[6], Ching-Ren Lin[2]

1. Department of Geosciences, National Taiwan University, 2. Academia Sinica, 3. National Taiwan Normal University, 4. National Applied Research Laboratories, 5. JAMSTEC, 6. University of the Ryukyus

We conduct a multiscale finite-frequency tomography of upper mantle structure beneath the northern Ryukyu subduction zone, where the Philippine Sea Plate (PSP) subducting beneath the Eurasian continent forms a trench-forearc-arc-backarc system. The data comprises of vertical-component P waveforms of teleseismic earthquakes with epicentral distance of 30°-95° and magnitude greater than 5.5 recorded by 3 island stations from the F-net network of Japan and 26 broadband ocean-bottom seismometers from the Taiwan-Japan collaborative experiment deployed between Sept. 2018 and June 2019 in the study area. Relative traveltime residuals between the recording stations for each event are measured by cross correlating the band-pass filtered waveforms at periods of 8-20 s. Those with the cross-collelation coefficients > 0.8 are retained for the tomographic inversion of 3-D P-wave velocity perturbations at least down to the depth of 300 km. Data-adaptive, finite-frequency traveltime kernels in conjunction with multiscale wavelet-based parameterization are adopted to resolve the multi-resolution velocity structure. The resulting model reveals a low-velocity anomaly in the forearc wedge and a high-velocity lid in the uppermost 80-km depth beneath the northern Okinawa Trough (NOT) and Ryukyu arc which may correspond to the overriding Eurasian continental lithosphere. Besides, a trench-parallel elongated fast anomaly extending at least down to ~200 km depth and most likely associated with the subducted PSP slab is observed under the NOT. Further appraisal of model resolution and S-velocity structure will be undertaken to verify these resulting seismic features.

[Invited] Active and passive seismic investigations in the Ryukyu Trench and the Okinawa Trough: A review of 7-year achievements by JAMSTEC

*Ryuta Arai[1], Shuichi Kodaira[1], Tsutomu Takahashi[1], Ayako Nakanishi[1], Yojiro Yamamoto[1], Yuka Kaiho[1], Yasushi Ishihara[1], Seiichi Miura[1], Yoshiyuki Kaneda[1,2]

1. JAMSTEC, 2. Kagawa University

The Ryukyu subduction zone in southwestern Japan hosts a variety of slow earthquakes and thus is an ideal study field to understand the physical controls on slip behaviors along the plate boundary. The Okinawa Trough, an active back-arc basin behind the Ryukyu arc, also provides a superb site for studying the lithospheric evolution associated with the continental rifting process. However, the background structure of this trench-arc-backarc system and physical properties of faults accommodating the plate subduction and back-arc rifting have been poorly documented. To better understand the seismogenic, volcanic and tectonic processes around the Ryukyu arc, JAMSTEC have been conducting intensive seismic investigations since 2013 as part of “Research Project for compound disaster mitigation on the great earthquakes and tsunamis around the Nankai Trough region”. This project consists of across-arc active-source seismic surveys, including multichannel seismic reflection profiling and refraction studies using ocean bottom seismographs, and passive onshore/offshore seismic observations. In this presentation, we will give a brief review of our achievements over the last seven years.

In the southern Ryukyu Trench off Ishigaki Island where a large tsunami earthquake occurred in 1771 (Nakamura, 2009), we found evidence for thin low-velocity zones along the plate interface at 5-22 km depths and interpreted them to be caused by high fluid pressure (Arai et al., 2016). This fluid-rich plate boundary hosts low-frequency earthquakes at 15-18 km depths and suggests that a strongly-coupled zone, which is typical at these depths in other subduction zones, may be missing. The passive seismic observations also confirmed that the low-frequency earthquakes are located close to but do not overlap regular earthquakes (Yamamoto et al., 2018). This spatial pattern of seismicity suggests that the frictional properties along the plate boundary may vary not only in the dip direction but also along the strike.

On the back-arc side of the southern Ryukyu arc, we revealed symmetrical rift system across the rift axis (Yaeyama Rift) characterized by dense inward-dipping normal faults in the back-arc basin (Arai et al., 2017a). The rift structure accompanies narrow axial intrusions resulted from passive upwelling of magma which drive hydrothermal venting at the seafloor and seismic swarms at the shallow crustal depths.

In the northern Ryukyu Trench off Amami-Oshima Island where the Amami Plateau collides with the overriding plate, we found that the subducting plate is vertically displaced and forms obvious normal-fault steps of over 1 km at the plate interface (Arai et al., 2017b). This slab-intersecting faults are located at the downdip of the subducting seamount and are active as evidenced by large normal-fault earthquakes in 1995. These findings suggest that internal heterogeneities of the slab, especially significant buoyancy acting on the thick oceanic plateau, can produce sufficient differential stress leading to high-angle normal-fault earthquakes within the slab. We also found a number of slab seismicity in the forearc region east off Tanegashima Island and suggest that, same as the southern Ryukyu Trench, there is a clear spatial separation between regular earthquakes and slow earthquakes (Yamamoto et al., 2020).

In contrast to the southern Okinawa Trough, the overall faulting style in the northern Okinawa Trough is significantly asymmetric and rapidly transitions from normal faults to strike-slip faults (Arai et al., 2018). We also detected evidence for active magmatic intrusions around the volcanic front, suggesting that the volcanism in the northern Ryukyu arc is robustly supported by magmatic supply from the subducting slab. The overall rift system in the Okinawa Trough are thought to be controlled by the along-trough variation in extension rate as well as the strength and thermal structure of the plate.