Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS01-01 会場:102B 時間:5 月 24 日 14:15-14:30

確率密度比推定を用いた前震のリアルタイム識別
Real-time Classifier of Foreshocks Using Probability Density Ratio Estimation

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前震は大地震の短期予測において一つの有効な手段である。過去多くの大地震について前震が観測されているが、本震が起こるより前に前震を識別することは困難な課題である。前震を事前に完全に識別することは困難であるものの、前震の位置情報や規模あるいは時間的情報などを利用して、前震であることを確率的に評価する研究はこれまでに多くなされてきた。
本研究では、確率密度比推定を用いて前震の確率的識別関数を構成する手法を提案する。確率密度比推定は統計的機械学習の一つの枠組みであり、高次元空間上での 2 クラス判別を確率的に与える手法である。更新されるカタログから随時追加的に学習することができ、リアルタイムでの前震識別を与えることが可能となる。識別関数にはカーネル関数を利用することで、空間的情報や時間的情報などを組み合わせた高次元空間上に非線形な判別境界を設けることができる。
本研究では、気象庁の一元化カタログに本手法を適用して、震源位置、時間、マグニチュードなどの情報から前震確率を評価する識別関数を推定する。また、推定された識別関数を独立した過去のカタログに適用して、予測性能の評価を行う。

キーワード: 前震, 確率的識別, 確率密度比推定, カーネル法
Keywords: foreshock, probabilistic recognition, probability density ratio estimation, kernel method

SSS01-02 会場:102B 時間:5 月 24 日 14:30-14:45

余震予測における不確定性
Forecast uncertainty in aftershock forecasting

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Aftershock forecasting provides one of the important measures for mitigation of earthquake damages. For this purpose, statistics- and physics- based models have been developed. When forecasting using these models, we usually adopt an optimal single set of parameter values such as the maximum likelihood estimates, which is called as plug-in forecasting. However, for a given small sized and incomplete data shortly after the main shock, the estimation of the model parameters may be accompanied by large uncertainty. In such a case, the plug-in forecasting underestimates the predictive probability range, and sometimes the range significantly biases the actual observations. Alternatively, more robust and unbiased forecasts can be obtained by considering the estimation uncertainty in an appropriate way. Bayesian forecasting provides a consistent statistical framework for this, and enables us to assess the forecast uncertainty. In this talk, we will argue the importance of evaluating the forecast uncertainty in probabilistic forecasting. As an example here, we employ the epidemic type aftershock sequence (ETAS) model as a forecasting model, and we show how the plug-in forecasting can fail and how the Bayesian forecasting can improve the performance. We will argue that the Bayesian predictors should also be tested in CSEP forecasting experiments.

Reference: T. Omi, Y. Ogata, Y. Hirata, & K. Aihara, ”Intermediate-term forecasting of aftershocks from an early aftershock sequence: Bayesian and ensemble forecasting approaches”, JGR (in revision).

キーワード: 余震予測, 確率点過程, ベイズ予測
Keywords: Aftershock forecasting, Point process, Bayesian forecasting

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SSS01-03 会場:102B 時間:5 月 24 日 14:45-15:00

関東地方における2011年東北地方太平洋沖地震による静的クーロン応力変化と地震活動度変化の相関性
Correlation between Coulomb stress imparted by the 2011 Tohoku-Oki earthquake and seismicity rate change in Kanto, Japan

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ISHIBE, Takeo[1*] ; SATAKE, Kenji[1] ; SAKAI, Shin'ichi[1] ; SHIMAZAKI, Kunihiko[1] ; TSURUOKA, Hiroshi[1] ; YOKOTA, Yusuke[2] ; NAKAGAWA, Shigeki[1] ; HIRATA, Naoshi[1]

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We show that the seismicity rate increase in the Kanto region around Tokyo following the 2011 Tohoku-Oki earthquake (Mw9.0) was well correlated with the static increases in the Coulomb failure function (ΔCFF) transferred from the Tohoku-Oki earthquake sequence. Because earthquakes in the Kanto region exhibit various focal mechanisms, the receiver faults for the ΔCFF were assumed to be reliable focal mechanism solutions of ˜3,000 earthquakes compiled from three networks (F-net, JMA network, and MeSO-net).

The histograms of ΔCFF showed that more events in the postseismic period had positive ΔCFF values than those in the preseismic period (2008 April 1 - 2011 March 10). Among the 928 receiver faults showing the significant ΔCFF with absolute values $\geq$ 0.1 bars in the preseismic period, 717 receiver faults (77.3 %) indicated positive ΔCFF. On the contrary, 1,334 (88.2 %) out of 1,513 receiver faults indicated positive ΔCFF in the postseismic period. We confirmed that the result is similar for the longer preseismic period, between 1997 October 1 and 2011 March 10.

To test the significance of the difference in the distribution of ΔCFF between preseismic and postseismic periods, we used a Monte Carlo method with bootstrap resampling. As a result, the ratio of positive ΔCFF randomly resampled from ΔCFF values in the preseismic period never exceeded 83.1%, even after 10,000 iterations. This supports the findings of Toda & Stein [2013]; however, our calculation is more reliable than theirs because we used a much larger number of focal mechanisms compiled from the three networks. It also proves that the static stress changes transferred from the Tohoku-Oki earthquake sequence are responsible for the changes in the seismicity rate in the Kanto region.

Earthquakes of focal mechanisms with positive ΔCFF values drastically increased, while those with negative ΔCFFs showed no obvious changes except for immediately after the mainshock. This fault-dependent seismicity rate change strongly supports the contribution of the Coulomb stress transferred from the Tohoku-Oki sequence to the seismicity rate change in the Kanto region. Immediately following the mainshock, earthquakes of all types of focal mechanisms were activated, but the increased seismicity rate of earthquakes with negative ΔCFFs returned to the background level within a few months. This suggests that there might be other contributing factors to the seismicity rate change such as dynamic stress triggering or pore-fluid pressure changes.

Acknowledgements
This study was supported by the Special project for reducing vulnerability for urban mega earthquake disasters from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

キーワード: 2011 年東北地方太平洋沖地震, 地震活動度変化, 関東地方, 静的クーロン応力変化
Keywords: 2011 Tohoku-Oki earthquake, Seismicity rate change, Static changes in the Coulomb failure function, Kanto region

SSS01-04 会場:102B 時間:5 月 24 日 15:00-15:15

CSEP-Japan testing results with multiple runs since 2009 including the 2011 Tohoku-oki earthquake

CSEP-Japan testing results with multiple runs since 2009 including the 2011 Tohoku-oki earthquake

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It is 5 years since we have established the Japanese testing center for the Study of Earthquake Predictability (CSEP) in Earthquake Research Institute, the University of Tokyo. During the period of testing, in 2011 March, Tohoku-oki earthquake with M9.0 occurred and seismic activity changed very much in entire part of Japanese Islands.

The CSEP Japan testing experiment consists of 12 categories, with 4 testing classes with different periods (1 day, 3 months, 1 year and 3 years) and 3 testing regions called“AllJapan,”“Mainland,”and“Kanto.”Starting from 91 models in September 2009, a total of 160 models, as of January 2015, are currently under testing in the CSEP official suite with collaboration of CSEP Testing Center at the Southern California Earthquake Center (SCEC) (Nanjo et al., 2011; Tsuruoka et al., 2012). For 3-month and one-year testing experiments, more than 15 runs of fully prospective experiments have been operated. Probability gains of tested models with respective to a spatially uniform probability model show that some models have always better performances in regions of AllJapan and Kanto, but the best model varies rounds by rounds for the region of Mainland.

In the testing period including the 2011 Tohoku-oki earthquake, a model which has wider spatial smoothing radius of 100km of Relative Intensity Model (RI) shows larger probability gain than those with a narrow smoothing while in other periods a small smoothing radius of 10 km shows better performance. Probability gains of models for 3-month and 1-year testing class for each model are almost same although a magnitude of target events is different. A model of HISTETAS5PA (Ogata, 2011) shows best performance for 1 day class and a region of AllJapan before the 2011 Tohoku-oki event but after the event ETAS (Zhuang, 2011) is better than HISTETAS5PA.

キーワード: CSEP, 地震予測
Keywords: CSEP, Earthquake Predictability

SSS01-05 会場:102B 時間:5 月 24 日 15:15-15:30

東北地方太平洋沖地震後の地震活動の予測
Forecasting seismicity after the Tohoku-Oki earthquake

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M9.0 の 2011 年東北沖地震が発生して以来 4 年が経たった。この超巨大地震は依然として日本周辺の現在および将来の地震活動に影響を与えている。この機会に、将来の地震活動のさまざまな予測について議論したい。さらに将来の地震をより細かく予測するための統計モデルの高度化の計画について説明したい。

キーワード: 確率予測, ETAS モデル, 誘発地震, 時空間 ETAS モデル, マグニチュード分布, 地震検出率
Keywords: Probability forecast, ETAS models, Triggering seismicity, Space-time ETAS model, Magnitude distributions, Earthquake detection rates

Japan Geoscience Union Meeting 2015
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SSS01-06 会場:102B 時間:5 月 24 日 15:30-15:45

Post-Disaster Damage Mapping as Tool for Risk Testing
Post-Disaster Damage Mapping as Tool for Risk Testing

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The Post-Disaster Damage Mapping is part of the Global Dynamic Exposure project, in which we interpret and visualize crowd-sourced and open geographic data and provide guidance to what is called the crowd in data collection. We base our work on OpenStreetMap (www.openstreetmap.org) because of the fully open geographic data and the availability of open-source software for processing the data. Because of the immense number and variety of buildings, exposure- and vulnerability-related data cannot be compiled by a small group. Furthermore, the dynamic aspect of risk, namely rapid urbanization, requires monitoring of exposure and vulnerability indicators, again a task that can only be achieved when distributing the work onto many shoulders.

The objective of the Global Dynamic Exposure project is to provide a high-resolution (on the building-by-building level) and dynamic (low-latency) exposure model for the world. It will build upon the Global Exposure Database for the Global Earthquake Model (GED4GEM) and augment it where crowd-sourced and open data exists in high quality and high density. The exposure and vulnerability indicators are derived from geographic data (e. g. building footprint, land use), building properties (e. g. type of building, occupancy), and semantic interpretation (e. g. regional types of architecture, cultural habits). Once a target area is fully captured in OpenStreetMap, further changes in the dataset indicate the change of building stock or the process of urbanization. This dynamic aspect of data collection is used for the Post-Disaster Damage Mapping. Here, the so-called Humanitarian OpenStreetMap Team (hot.openstreetmap.org), a crowd-sourced disaster mapping effort, is providing information about the status of buildings and roads in the aftermath of a disaster. These data is retrieved mainly from aerial imagery but also from mappers on the ground.

Combining the exposure and vulnerability data of buildings prior to a natural disaster with the post-disaster damage status will provide a new dataset for better understanding risk and the societal impact of a catastrophe, but will also for the first time offer an independent dataset for testing risk estimates.

キーワード: risk testing, seismic hazard, seismic risk, exposure, vulnerability
Keywords: risk testing, seismic hazard, seismic risk, exposure, vulnerability

Japan Geoscience Union Meeting 2015
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SSS01-07 会場:102B 時間:5 月 24 日 15:45-16:00

USGS 全国地震動予測地図と DYFI 観測震度の比較
Comparing USGS national seismic hazard maps with DYFI intensity observations

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Verifying a nationwide seismic hazard assessment using data collected after the assessment has been made (i.e., prospective data) is a direct consistency check of the assessment. We directly compared the predicted rate of ground motion exceedance by the four available versions of the USGS national seismic hazard map (NSHMP, 1996, 2002, 2008, 2014) with the actual observed rate during 2000-2013. The data were prospective to the two earlier versions of NSHMP. We used three sets of somewhat independent data, namely 1) the USGS ”Did You Feel It?” (DYFI) intensity reports, 2) ShakeMap gridded ground motions, and 3) instrumental ground motion records extracted from ShakeMap stations. The first two were not strictly observations but models calibrated by observations. The third was true observation but the amount of data is limited.

Our results indicated that for California, the predicted and observed hazards are very comparable. Discrepancy lied generally on the safe side (i.e., predicted hazard not lower than the observed one). The three sets of data gave consistent results, implying robustness. The consistency also encourages the use of DYFI and ShakeMap data for hazard verification in the central and eastern US (CEUS), where instrumental records are lacking. The result showed that the observed ground-motion exceedance was larger than the predicted in CEUS, implying a possible underpredicted hazard.

The primary value of this study is to demonstrate the usefulness of DYFI and ShakeMap data, originally designed for community communication instead of scientific analysis, for the purpose of hazard verification. The large discrepancy between the observed and predicted gorund-motion exceedance in CEUS implied that either the ground motions were not described correctly by DYFI and ShakeMap for the region, or the hazard was actually underestimated. Induced seismicity could be the cause of this underestimation.

キーワード: 地震ハザード, 予測, 検証
Keywords: Earthquake Hazard, Prediction, Validation

Japan Geoscience Union Meeting 2015
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SSS01-08 会場:102B 時間:5 月 24 日 16:15-16:30

Detecting spatial variations of earthquake clustering parameters via maximum weighted likelihoods estimates
Detecting spatial variations of earthquake clustering parameters via maximum weighted likelihoods estimates

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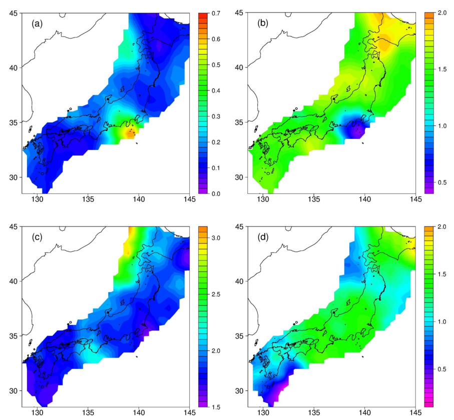
The ETAS model has been used to describe the clustering features of seismicity with just several parameters. To see how the clustering parameters and background rates change spatially, in this study, the earthquake data from the JMA catalog are used and these model parameters are estimated by using the maximum weighted likelihood estimate (MWLE) method. Even though this MWLE method is not as sophisticated as the HIST-ETAS model, which is built on a more rigorous basis of the Bayesian procedure with the smoothness prior, MWLE is simpler to implement, in both parallel and non-parallel computing environments, without loss of detecting resolution of the spatial variation of earthquake clustering parameters.

The data analysis shows that the spatial variation of the MWLEs of each parameter shows different features between tectonic regions. Also, applying the MWLE method has the potentials for improving the forecasting performance of the space-time ETAS model in evaluating earthquake probabilities.

Figure 1: Spatial variations of the ETAS parameters estimated by using maximum weighted likelihood estimate (MWLE). (a) A, (b) α, (c) q, (d) γ.

キーワード: ETAS モデル, 地震クラスタ, 地震予測, 最大重み付き尤度推定値
Keywords: ETAS model, earthquake cluster, earthquake forecasting, weight likelihood estimator



SSS01-09 会場:102B 時間:5 月 24 日 16:30-16:45

地震発生回数の頻度分布
Frequency distribution of the number of earthquake occurrence

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前震や余震があることからも明らかなように，地震活動には，互いに相関のある活動が含まれる．そのため，地震数の頻度分布をポアソン分布で表すことは難しいと思われるが，実態に近い分布関数について検討した．これは，地震活動の一面を理解する上で必要なことであり，また，正しい頻度分布がわかっていないと適確な予測の評価を行うことができない．

地震数の頻度分布は，これまでしばしば負の２項分布で表されてきた．しかしそれは，概してデータセットの平均 r が大きい場合（例えば r>>1 ）であり，希にしか地震が起こらないデータセットについては，疑問に思われる．小さな平均の場合，分布は負のべき分布に近い．そこで筆者らは先に，地震発生頻度の分布関数として，離散ガンマ分布を提案した（ f(x) = c (x^-a) exp(-bx): Yamashina et. al, 2012）．一方，もうひとつの候補として，ここでは負の離散ガンマ分布を取り上げる (f(x) = c (x^-a) exp(-b/x))．両関数は，大きな平均をもつデータセットから小さな平均のものまで，広い範囲でかなりよく実際の分布事例に当てはめることができるが，特に大きな平均をもつ場合について，後者の方が当てはまりがよい傾向がある．

ここで取り上げた関数は，ａが正のときにはｘ＝０で発散するが，ｘ＝１以上について適用する．これは，例えばｘ＝２の頻度はｘ＝１の頻度と関係するものの，ｘ＝０の頻度との相関は小さいと思われ，ｘ＝０，１，２を同じ分布関数で表現することは難しいと考えられたからである．ｘ＝０の頻度は，他の頻度を合計した残りとする．

ＣＳＥＰプロジェクトの地震活動予測において，予測値がどのくらい実状に合っていたかどうかを評価する際，現在は，地震発生回数の頻度がポアソン分布だとみなして行っている．しかし，実態を必ずしも反映しない頻度分布を前提にしたのでは，評価した結果に疑問を残す．今後，実態に合う頻度分布を評価に取り入れたときにどのような違いが生じるかなど，確かめることが望まれる．

キーワード: 頻度分布, 地震発生回数, CSEP
Keywords: frequency distribution, number of earthquake occurrence, CSEP

Japan Geoscience Union Meeting 2015
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SSS01-10 会場:102B 時間:5 月 24 日 16:45-17:00

History of network detection completeness in Japan
History of network detection completeness in Japan

SCHORLEMMER, Danijel[1*] ; HIRATA, Naoshi[2] ; ISHIGAKI, Yuzo[3] ; NANJO, Kazuyoshi[4] ; TSURUOKA, Hiroshi[2] ; BEUTIN, Thomas[1] ; EUCHNER, Fabian[5]
SCHORLEMMER, Danijel[1*] ; HIRATA, Naoshi[2] ; ISHIGAKI, Yuzo[3] ; NANJO, Kazuyoshi[4] ; TSURUOKA, Hiroshi[2] ; BEUTIN, Thomas[1] ; EUCHNER, Fabian[5]

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An important characteristic of any seismic network is its detection completeness, which should be considered a function of space and time. Many researchers rely on robust estimates of detection completeness, especially when investigating statistical parameters of earthquake occurrence like earthquake rates. Contrary to traditional approaches, we do not estimate completeness using methods in which the completeness magnitude is defined as the deviation of the frequency-magnitude distribution from the linear Gutenberg-Richter relation. Here, we present a method based on empirical data only: phase data, station information, and the network-specific attenuation relation. For each station of the network we estimate a time-dependent distribution function describing the detection capability depending on magnitude and distance to the earthquake. For each point in time, maps of detection probabilities for certain magnitudes or overall completeness levels are compiled based on these distributions. Therefore, this method allows for inspection of station performances and their evolution as well as investigations on local detection probabilities even in regions without seismic activity.

We present a full history of network detection completeness for Japan and discuss details of this evolution. These results are compared with estimated completeness levels of other methods and with completeness levels in other regions of the World. We present scenario computations showing the impact of different possible network failures. All presented results are published on the CompletenessWeb (www.completenessweb.org) from which the user can download completeness data from all investigated regions, software codes for reproducing the results, and publication-ready and customizable figures.

キーワード: catalog completeness, earthquake recording, statistical seismology, earthquake statistics, earthquake forecasting, seismic hazard
Keywords: catalog completeness, earthquake recording, statistical seismology, earthquake statistics, earthquake forecasting, seismic hazard

SSS01-11 会場:102B 時間:5 月 24 日 17:00-17:15

Assessment of optimal short-term earthquake forecasts based on ULF seismo-magnetic data

Assessment of optimal short-term earthquake forecasts based on ULF seismo-magnetic data

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Our previous statistical studies have indicated that the ULF seismo-magnetic phenomena contain precursory information and can be useful in short-term forecasting of sizable earthquakes. In practice, for given series of precursory signals and related earthquake events, the efficiency of forecast is a function of the leading time of alarms (Δ) and the length of alarm window (L). To find out the best prediction strategies, Molchan's error diagram has been employed. The same as our previous study, we utilized geomagnetic data and earthquake events registered in Kakioka (KAK), Japan during 2001-2010. Ratios of observed energy to modeled background are applied to indentify precursory signals. A modified area skill score, which measures the area between actual prediction curve and random prediction line, is introduced to assess the efficiency of different prediction strategies. The results indicate that ULF magnetic data at KAK contains higher precursory information when Δ is around 1 week and L is less than 4 days or Δ is 13-14 days and L is less than 1 week; the optimal strategy of short-term forecasts is: Δ =8 days and L =1 day. The methodology proposed in this study could help to evaluate the prediction policy and find out the optimal solution of other different measurements for short-term earthquake forecasting.

キーワード: ULF seismo-magnetic phenomena, Molchan's error diagram, optimal short-term earthquake forecast
Keywords: ULF seismo-magnetic phenomena, Molchan's error diagram, optimal short-term earthquake forecast

SSS01-12 会場:102B 時間:5 月 24 日 17:15-17:30

Earthquake mechanism in post-megathrust intraplate stress
Earthquake mechanism in post-megathrust intraplate stress

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Megathrusts produce large permanent lithospheric displacements as well as strong transient ground shaking up to regional distances. The lateral permanent displacements construct stress shadows in a wide backarc region. The Korean Peninsula is placed in the far-eastern Eurasian plate that belongs to a stable intraplate region with a low earthquake occurrence rate and diffused seismicity, and is located in the backarc at ~1300 km in the west from the epicenter of the 11 March 2011 M9.0 Tohoku-Oki earthquake. The seismicity around the Korean Peninsula was increased significantly after the 2011 M9.0 Tohoku-Oki earthquake, which is not consistent with the expected seismic-quiescence. Strong seismic waves cause large dynamic stress changes, incurring fluid migration and increasing pore fluid pressure in the media. The lithospheric displacements directing to the epicenter on the convergent plate boundary develop transient radial tension field over the backarc lithospheres, which is subparallel with the preseismic ambient compressional field. The pore pressure growth and radial tension field decrease the Coulomb failure stress, increasing episodic increases of seismicity in both fault zones and intact media. The ambient stress field is recovered gradually as the induced stress field diminishes with time by tectonic loading. The seismicity changes with the temporal evolution of stress field. A series of moderate-size earthquakes and earthquake swarms occur as a consequence of medium response to the temporal evolution of stress field. The long-term evolution of seismicity is expected to continue until the preseismic ambient stress field is fully recovered.

キーワード: stress shadow, intraplate, megathrust, long-term evolution, Korean Peninsula
Keywords: stress shadow, intraplate, megathrust, long-term evolution, Korean Peninsula

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2011 年東北地方太平洋沖地震後の日本内陸における地震活動変化の概観とその解釈
Overview of Widespread Seismicity Changes inland Japan Following the 2011 Tohoku-Oki Earthquake and Its Interpretation

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This paper overviews the widespread changes in seismicity rate and distribution of focal mechanism after the Tohoku-Oki earthquake (Mw9.0) and summarize possible contributing factors.

In the Tohoku region, significant increases in seismicity rate were observed in N. and S. Akita, SW off Oga peninsula, and Yamagata/Fukushima boundary area as well as other surrounding areas. The most activated area was the Ibaraki/Fukushima boundary area where shallow normal-faulting earthquakes abruptly began to occur. On the other hand, swarm-like activity in the south of Lake Inawashiro suddenly terminated following the Tohoku-Oki earthquake. In addition, aftershock activities in the source regions of recent large earthquakes such as the 2008 Iwate-Miyagi earthquake (M_{JMA}7.0) have been suppressed. Focal mechanism distributions also showed significant changes in the shallow crust of the Tohoku region; strike-slip and normal-faulting earthquakes were activated following the Tohoku-Oki earthquake, while thrust-faulting earthquakes, which had been predominant due to the compression in the E-W direction, were deactivated.

In the Kanto region, abrupt increases in seismicity rate of the shallow crustal areas were typically observed in the Tochigi/Gunma and Ibaraki/Chiba boundary areas, SE Chiba near Choshi City, N. Tokyo Bay area, SE part of Boso peninsula, Tanzawa, Hakone, and Izu areas. Furthermore, two moderate earthquakes (the earthquake near the prefectural boundary between Nagano and Niigata (M_{JMA}6.7) on March 12th and the earthquake in the E. Shizuoka prefecture (M_{JMA}6.2) on March 15th) occurred. At intermediate depths, interplate earthquakes associated with the subduction of the Philippine Sea Plate (PHS) and the Pacific Plate (PAC) were activated, especially in SW Ibaraki, NE, NW, and SE Chiba areas. Belt-like seismicity that extended from the S. Miura Peninsula to the SW off Chiba area through the S. Boso peninsula, at a depth of 60-70 km, was also activated.

The most plausible factor which caused the changes in seismicity is the static changes in the Coulomb stress transferred by the Tohoku-Oki earthquake which make it possible to retrospectively forecast the changes in seismicity on some level. However, some activated seismicity showed clear counter-evidence. A typical example is a thrust-faulting earthquake sequence which started one week after the mainshock in Yamagata/Fukushima boundary area. The calculated stress changes were negative for most of focal mechanisms of post-Tohoku earthquakes.

Many remotely triggered local events, whose origin times are well coincided with the arrival of seismic waves from the Tohoku-Oki earthquake, suggest that dynamic stress changes due to the passage of seismic waves also contribute seismicity changes. Some swarm-like activities induced by the Tohoku-Oki earthquake such as those in the Yamagata/Fukushima boundary clearly show temporal expansion of the focal area, which is attributed to fluid diffusion. It suggests that pore fluid pressure changes are another possible factor because decreases in failure strength due to increases in pore fluid pressure can also enhance the faulting. The contribution of indirectly triggered earthquakes might be very important in some areas because stress changes imparted by neighboring indirect aftershocks could be comparable with or larger than those from a distant mainshock. Postseisimc slip now observed by GEONET and viscoelastic effect would play an important role for long-term seismicity rate change.

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キーワード: 2011 年東北地方太平洋沖地震, 地震活動変化, 静的・動的応力変化, 間隙流体圧変化, 余効すべり, 粘弾性効果
Keywords: 2011 Tohoku-Oki earthquake, Seismicity change, Static and dynamic stress changes, Pore fluid pressure change, Postseismic slip, Viscoelastic effects

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首都圏の地震発生予測モデルの構築に向けて：レトロスペクティブテストによる予測条件の探索とプロスペクティブテストの経過報告
Three-dimensional earthquake forecasting model for the Kanto district:Results of retrospective and prospective tests

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関東地方は本州弧の地殻内からフィリピン海スラブ、太平洋スラブに関連した浅発および稍深発地震の活動が活発であり、地震発生頻度の高い「深さ」が存在する。そこで私達は、地震活動の評価に基づく地震発生予測検証実験の「関東領域」と比較可能な予測領域で発生する地震の経度・緯度・深さを精度よく予測する三次元地震発生予測モデルを構築することを目的として 2012 年から研究を開始した。これは、Relative Intensity モデル（以下、RI モデルとする。Nanjo, 2011）[EPS, 63 (3) 261-274] を土台とし、三次元地震発生予測モデルを作成するものである。RI モデルは過去の地震活動から将来の地震活動を予測する統計モデルなので、その予測は使用するデータ（地震カタログ）の質の影響を受ける。そこで、Maximum curvature method (Wiemer and Wyss, 2000) [BSSA, 90 (4) 859-869] により地震カタログの品質評価を行い、気象庁一元化地震カタログの下限マグニチュード（Mc）が 1980 年以降は 2 以下で時間的に安定していることを確認した。そこで、Mc の品質が良く、かつ 2011 年東北地方太平洋沖地震の直前である 1998 年 1 月 1 日から 2011 年 2 月 1 日の気象庁一元化地震カタログを使用してレトロスペクティブテスト（遡及的予測実験）を行い、三次元予測空間の分解能を 0.05° x0.05° x 5km とした。この空間分解能において RI モデルは二次元予測空間よりも良い予測成績を示した。次に、プロスペクティブテスト（事前予測実験）を開始した。第 1 回目の予測実験は、2015 年 2 月 1 日から 3 ヶ月間（5 月 1 日まで）の M 4.0 以上の地震とした。学習条件は、M 2.5 以上、平滑化半径は 7.5、10、20、50 km とし、期間は以下の 3 種とした。1) 1998 年 1 月 1 日ー 2011 年 1 月 1 日：2011 年東北地方太平洋沖地震前の気象庁一元化地震カタログの確定値。2) 1998 年 1 月 1 日ー 2014 年 8 月 1 日：気象庁一元化地震カタログの確定値のみ。3) 1998 年 1 月 1 日ー 2015 年 1 月 1 日：気象庁一元化地震カタログの確定値と暫定値。予測期間終了後（2015 年 5 月 1 日以降）に『地震活動の評価に基づく地震発生予測検証実験』（三次元地震発生予測モデル用に改良したもの）と同様の方法で評価する。本発表では、レトロスペクティブテストでの二次元と三次元予測空間における RI モデルの成績の比較、及びプロスペクティブテストの第 1 回目の予測を気象庁カタログの暫定値で検証した結果を示す。気象庁地震カタログを使用しました。記して感謝します。なお本研究は文部科学省受託研究「都市の脆弱性が引き起こす激甚災害の軽減化プロジェクト」の一環として行われています。

キーワード: 三次元地震発生予測モデル, 関東地方, レトロスペクティブテスト, プロスペクティブテスト, 地震活動の評価に基づく地震発生予測検証実験
Keywords: Three-dimensional forecasting model, Kanto district, Retrospective forecasting, Prospective forecasting, Collaboratory for the Study of Earthquake Predictability

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Collaboratory for the Study of Earthquake Predictability & Global Earthquake Model - Testing Center Software Development

Collaboratory for the Study of Earthquake Predictability & Global Earthquake Model - Testing Center Software Development

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The Collaboratory for the Study of Earthquake Predictability (CSEP) aims to improve our understanding about the physics and predictability of earthquakes through rigorous and prospective testing of earthquake forecast models. CSEP operates four testing centers in California, New Zealand, Japan, and Europe running prospective, automated evaluations of more than 430 models. These testing centers are the technical infrastructure of CSEP and implement all procedures and protocols for rigorous testing and evaluation of earthquake prediction experiments. These experiments run in various testing regions and comprise forecast periods of one day to many years. The CSEP testing center software system is the general infrastructure of all CSEP testing centers and is now being used for earthquake early warning systems and geodetic transient detectors. The Testing and Evaluation Group of the Global Earthquake Model project at GFZ Potsdam is expanding the system to test intensity prediction equations and ground-motion prediction. We present the recent developments, the ongoing experiments, and introduce the structure of the software system.

キーワード: Earthquake forecasting, Seismic hazard, Statistical seismology, Earthquake statistics, Forecast testing, Software
Keywords: Earthquake forecasting, Seismic hazard, Statistical seismology, Earthquake statistics, Forecast testing, Software