Modification of the log-normal distribution model based on the small sample theory

*Masami Okada[1]

1.Meteorological Research Institute

Introduction

Log-normal distribution model based on the small sample theory is a statistical sophisticated model to calculate the probability of forthcoming repeating events on the renewal process. We prospectively forecasted probabilities for small interplate repeating earthquakes along the Japan Trench (Okada et al., 2012). The number of forecasts in four experiments from 2006 through 2010 was 528 of which 249 cases were filled with qualifying event. Total of probabilities of forecast was 212.9 which was surely less than 249 of observation and the probabilities was rejected by the N-test. The bias of lower probability is confirmed by numerical simulation with random numbers, too. Hence I tried to modify the LN-SST for better forecasting.

Method

Suppose n+1 random variables Xi=log(Ti) and Xf=log(Tf) obey a normal distribution N(μ,σ^2). Xf=log(Tf) represents the interval from the last event to the forthcoming one. Take the variable, as follows;

Z=sqrt((n-1/(n+1))*(Xf - Xmean)/S.

It is well known that the Z-variable follows a t- distribution with the n-1 degree of freedom. Here Xmean and S are mean and standard deviation of n variable of Xi. At forecasting time we can calculate the values of Xmean and S, then the expected distribution of Xf is calculated, too. The probability of events in the forecast period is given with the conditional probability from the distribution of Xf.

Possible reason of lower probability are as follows;

(1) The t-distribution spreads wider than standard normal distribution and has a lower peak of the distribution.

(2) The expression of the conditional probability is not linear, then the forecast probability may tend to lower.

Modification

It is possible improvements for LN-SST to correct the bias of lower probability and to improve forecast score, as follows;

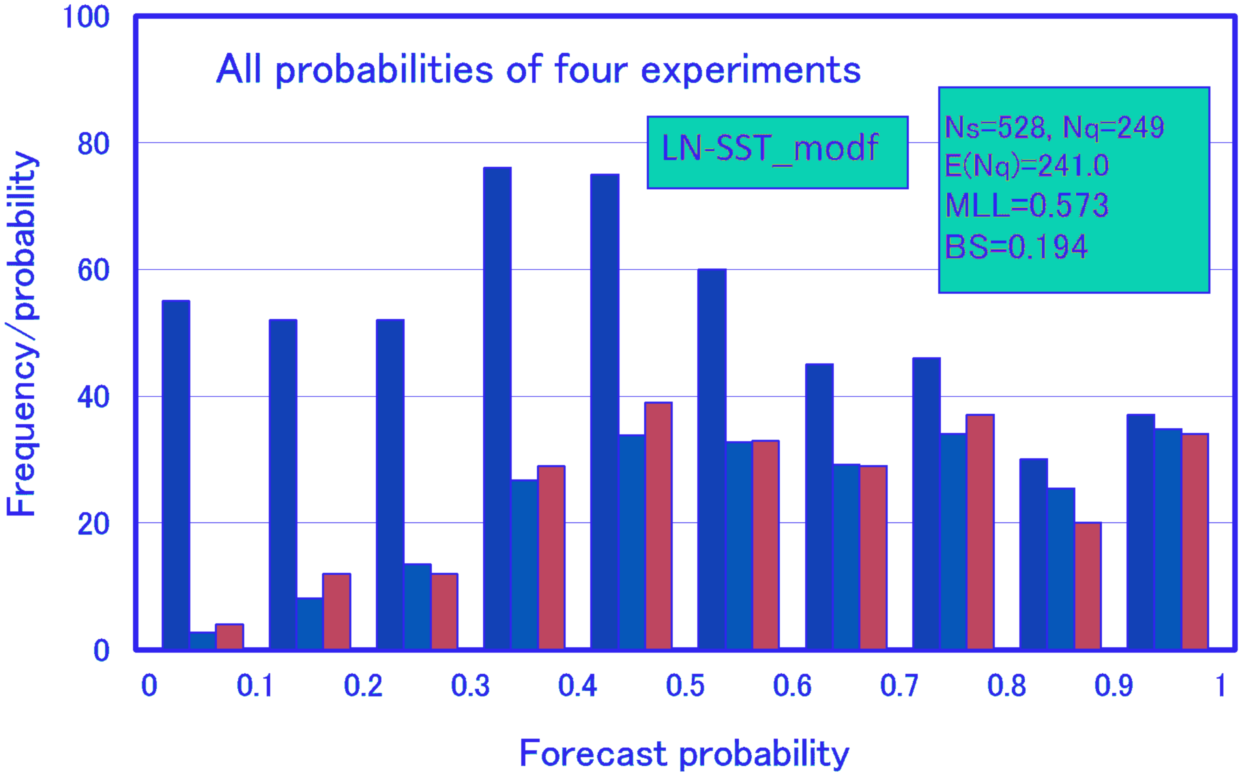
(1) Keep a definition of Z mentioned above intact and increase the degree of freedom.

If we raise one degree of freedom for the data of the experiment, the total of forecast probabilities increases to 217.0 from 212.9, and the results improve somewhat, too.

(2) Increase the probabilities with some quantity depending on calculated probability.

The original probability from 0 through 1 is converted with a formulae, y=log(p/(1-p)) into infinite interval, then suitable value (e.g., c=0.3) is added on y. Revised value is given by inverse conversion from y to probability. The total of forecast probabilities becomes 241.0, and the results is considerably improved (figure 1).

Keywords: repeating earthquake, forecast of earthquake, log-normal distribution, small sample theory


All probabilities of four experiments
LN-SST_modf
Ns=528, Nq=249
E(Nq)=241.0
MLL=0.573
BS=0.194
Frequency/probability
Forecast probability
0
20
40
60
80
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Statistical investigation of pre-seismic ionospheric disturbance from the in-situ plasma observation of the DEMETER

*Hidetoshi Nitta[1], Shoho Togo[1], Masashi Kamogawa[1], Jean-Jacques Berthelier[2], Tetsuya Kodama[3], Toshiyasu Nagao[4]

1.Department of Physics, Tokyo Gakugei University, 2.LATMOS, France, 3.Earth Observation Research, 4.Earthquake Prediction Research Center, Tokai University

We investigate ionospheric disturbance observed by the DEMETER plasma probes, which are ISL (Electron density and temperature) and IAP (Ion density and temperature). Since there are several papers concerning the pre-seismic ionospheric disturbance by using the data of electron/ion densities and temperature, we verify the reported pre-seismic anomalies by means of superposed epoch analysis. From the whole data set of the DEMETER, the superposed epoch analysis showed that the plasma disturbance appeared near the epicenter around 40 hours before the earthquakes. On the other hand, in the case of randomly generated earthquake catalogue, no similar anomalies appeared.

Keywords: Earthquake, DEMETER, Ionosphere

Earthquake occurrence rate after pre-seismic-like ionospheric disturbance appearance using the DEMETER data

*Shoho Togo[1], Hidetoshi Nitta[1], Masashi Kamogawa[1], Jean-Jacques Berthelier[2], Tetsuya Kodama[3], Toshiyasu Nagao[4]

1.Department of Physics, Tokyo Gakugei University, 2.LATMOS, France, 3.Earth Observation Research, 4.Earthquake Prediction Research Center, Tokai University

We statistically investigate pre-seismic ionospheric disturbances by using the VLF electric field data of the DEMETER, following Nemec et al. (Geophys. Res. Lett., 2008; J. Geophys. Res.; 2009) and Pisa et al. (J. Geophys. Res., 2013). Our replicated analysis also showed that the background intensity of around 1.7 kHz electric field decreased within 4 hours before the mainshock with magnitude of more than 4.8, using the complete data set of the DEMETER, i.e., 6.5-year.data (Figure 1a). In order to understand the physical mechanism of the depression of the background intensity, we selected 10 orbits highly related to the decrease of the intensity for the event analysis from the whole data. We applied statistical correlation to the whole data evaluating anomaly appearance rate and earthquake occurrence rate.

Keywords: Earthquake, DEMETER , Ionosphere

Evidence for the hypothesis of upwelling fluid from deep underground

*Tameshige Tsukuda[1]

1.none

Stress changes associated with crustal deformations may induce migration of fluid within the crust. It is hypothetically expected that a volume of pore water or fluid, being suddenly pressured in response to an elevated stress level in some seismogenic zone, will tend to intrude up into a crack network, and incidentally emerge at the ground surface or in the aquifer near ground surface. That hypothesis was presented in around 2005. The evidence at that time were as follows:
1) Frequent rises in well water temperature were observed at Iwakuni,Yamaguchi Prefecture, southwest Japan; 2) Gushing of groundwater at the sea bottom was considered to have occurred at the Akashi Strait 2 days before the 1995 Kobe earthquake of M7.3, based on an interpretation of the appearance of brownish-black seawater found by the captain of a passenger boat; 3) Upwelling of deep hot groundwater was occurred at Inagawa Town, Hyogo Prefecture, southwest Japan, which was associated with the 1995 Kobe earthquake. The well water temperature rose 3-4 ℃at the time of the shock, and decayed with a time constant of 1-2 years; 4) Heating of ground rocks by upwelling hot water intruding into the fracture zone of an active fault, which is considered to be a precursor for the April 1, 1995 Niigata-ken Hokubu earthquake of M5.5, was confirmed by a LANDSAT infrared image in the northern Niigata area, central Japan, on a summer night in 1994. All of the above transient phenomena can be reasonably understood in the light of the hypothesis of pressured hot water upwelling from deep underground in response to crustal movements around seismically active regions.
The amount of the upwelling fluids will change according to the pressure changes due to deformation of the crust. Shallow groundwater temperature will also change according to the change of the amount of the intruded hot water from deep underground. It should be noted that the 2009 Suruga-bay earthquake of M6.5 in Tokai area, central Japan, was accomapnied by precursory and after-effect changes of groundwater temperature. That kind of changes were not detected by the strain meters installed by JMA around the Tokai region. Precursory and after-effect temperature changes were found for other earthquake events such as the 2011 Tohoku earthquake of M9.0.

Keywords: deformation of the crust, pore fluid deep underground, groundwater temperature, precursory change

Maximum Magnitude of Subduction-Zone Earthquake around Eastern Japan Estimated by Seismic Moment Conservation Principle: Part 2

*Fuyuki Hirose[1], Kenji Maeda[1], Yasuhiro Yoshida[2]

1.Seismology and Tsunami Research Department, Meteorological Research Institute, 2.Meteorological College, Japan Meteorological Agency

Kagan & Jackson [2013, BSSA] estimated maximum magnitude of events which will occur along subduction zone in the world based on the seismic moment conservation principle by applying that to background seismicity from 1977 to 2010. The key point of this method is to replace total seismic moment rate with the tectonic moment rate M_T. Note that because the plate coupling rate χamong components of M_T has large uncertainty, the maximum magnitude obtained is dependent on χ. To avoid confusion, the magnitude and the seismic moment are represented by “m” and “M”, respectively.They modeled a seismic-moment-frequency-distribution by the truncated G-R law, tapered G-R law and Gamma distribution. These laws have two parameters: β(=b/1.5) and M_c (is characteristic seismic moment which represents the maximum magnitude. Corresponding magnitude is m_c). Truncated G-R law do not have events larger than m_c. Whereas tapered G-R law and Gamma distribution allow occurrence of events larger than m_c. Therefore, it is problematic to treat m_c of Tapered G-R law and Gamma distribution as the maximum magnitude.Hirose et al. [2014, SSJ] estimated m_c off Tohoku as 9.26 by the truncated G-R law if χis 60% by applying the seismic moment conservation principle to earthquakes occurred along the Kuril-Kamchatka-Japan trench from 1977 to 2013.There is also Utsu law with upper limit magnitude in addition to the truncated G-R law. In this study, we introduce the formulation of seismic moment conservation principle about Utsu law, and apply it to the same data set as Hirose et al. [2014, SSJ]. As the result, if assumed M_T (χ = 60%) is correct, the maximum magnitude of events which will occur off Tohoku in the future is estimated as 10.03. There is a possibility that the Tohoku-oki earthquake is not always the largest event in this area.

Keywords: Seismic moment conservation principle, Maximum magnitude, Utsu law

A Study on the Enhancing Earthquake Frequency in Northern Pakistan: Is the Climate Change Responsible?

*Muhammad Usman[1]

1.Space Geodesy Research Section,Division of Earth and Planetary Dynamics, Department of Natural History Science, School of Science, Hokkaido University

In northern Pakistan, the collision between Indian and Eurasian plates has resulted in the formation of many faults. The concentration of ruptures, in this regime, probably makes it sensitive to the localized changes in the stress. The current climate changes have caused an increase in the rainfall and variation in the mass of glaciers, present in the northern Pakistan. The rainfall and glacial runoff has potential to erode and transport sediments thus can change the balance of load across faults. On the other hand, glacial mass loss or gain also has potential of iso-static rebound or compression of crust, respectively. All these factors have been observed in the northern Pakistan. The seismic data of the duration 1965 to 2004 has been obtained from Pakistan Meteorological Department (PMD) and the sedimentation data has been acquired from Tarbela Dam Project (TDP). The study indicates a gradual increase in the earthquake frequency for the magnitudes 4.1-5.0(Mb). The epicental distributions show that these events gradually cluster in the central Karakorum and Hindukush areas. The depth analysis suggests the earthquakes with the foci 0-60km are gathering in the central Karakorum and shocks with depth 0-120 are clustering in the Hindukush areas. The FMS study exhibits the dominance of normal faulting in the central Karakorum after 1999 and these characteristics do not correspond with behavior of previous mapped Raikot Fault, lying in the vicinity. The known significant variables during the study period are the different geological processes associated with climate change, which have potential to alter the load across faults and can possibly result in enhancing earthquake frequency by releasing stresses at some local scale.

Keywords: Climate change, glacial mass change,, rising earthquake frequency

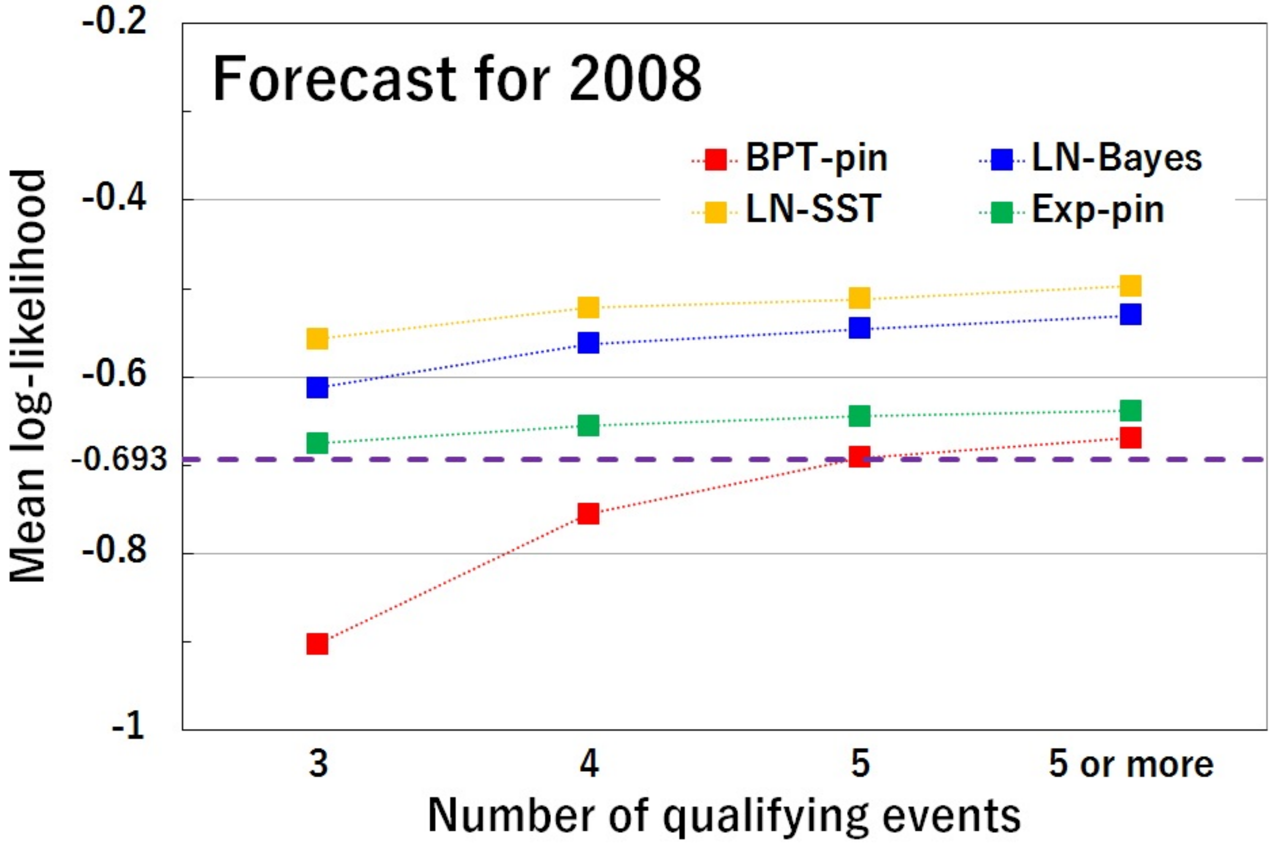
Long-term predictability for the repeating earthquake with a few times recurrence using the BPT model

*Masayuki Tanaka[1], Masami Okada[1]

1.Meteorological Research Institute

Event numbers of sequential recurrent large/medium earthquakes listed in seismic catalog are not so many, because they occur at long intervals. So, the probability of the next earthquakes must be calculated with a small number of data. We are studying the predictability by the BPT model using the 126 sequence of small interplate repeating earthquakes along the Japan Trench, which were used for the experiment of prospective forecast in 2008. Calculation was carried out with a small number of events. Events data was taken out in order of proximity from the last earthquake, by three, four, five and five or more.
We use BPT model to calculate the probabilities and three other models for comparison,
(1) BPT-pin: BPT distribution model. The parameters: the mean recurrence intervals, the average value of each series; the coefficient of variation, the median (α=0.367) of the values calculated in five events for each series.
(2) LN-Bayes: Lognormal distribution model with Bayesian approach. Probability distribution of recurrence interval is given with inverse gamma prior distribution. The parameters of inverse gamma are shape, φ=0.25 and scale, ζ=0.44.
(3) LN-SST: Lognormal distribution model base on the small sample theory.
(4) EXP-pin: Exponential distribution model. The parameter plugged is the sample mean.
The "Mean log-likelihood" mentioned below are used to score the forecast results.
Mean log-likelihood (MLL): Average of Ev*ln (P) + (1-Ev)* ln (1-P)
Here P means forecast probability for event and Ev means presence (Ev=1) or absence (Ev=0) of the event. If the Mean log-likelihood is larger than those of the alternative, the model is considered to be superior to the alternative one.
In Figure 1 the forecasts by four models become worse surely as the number of preceding events is smaller. The BPT-pin model is inferior to the other three of the statistical model. When the three qualifying events, the score is poor in the Exp-pin model, and it is below the results of the probability of 0.5 (MLL=-0.693).

Keywords: Repeating earthquakes, forecast, BPT model, Mean log-likelihood


Forecast for 2008
BPT-pin
LN-Bayes
LN-SST
Exp-pin
-0.2
-0.4
-0.6
-0.693
-0.8
-1
Mean log-likelihood
3
4
5
5 or more
Number of qualifying events

How often do the abnormal phenomena witnessed just before 1946 Nankai earthquake appear (1)

*Yasuhiro Umeda[1], Satoshi Itaba[1]

1.Advanced Industrial Science and Technology

Abnormal phenomena such as well water decreases or sea level changes has been witnessed just before the 1946 Nankai earthquake. In the Pacific Ocean coastal area of Shikoku from Kii peninsula, such phenomena have been witnessed in 24 locations. It has been witnessed that about 2m decrease of well water, maximum 3m lowering of sea level and about 0.5m of secondary undulation. It has been stable weather before the main shock. Do the witnessed abnormal phenomena has appeared only just before the main shock? Or do they occasionally appear? Based on the recent observation data, we examined the frequency with that the same phenomena as witnessed just before the main shock. The water level of three wells which have been reported the decreased water before the main shock have been observed continuously by AIST. In recent two years data, it was not found that the well water steeply decreases by more than 2m. We have searched the sea level departure at Kushimoto, Muroto cape and Kochi, on the JMA website. In 2003 - 2014, we could not find the sea level departure of more than -2m. The secondary undulations at Muroto cape were checked on the JMA website. In 2006-2014, there were 17 times of the secondary undulations more than 0.5m. All cases were caused by the weather. Within this survey, we could not find the similar abnormal phenomena which were witnessed just before the main shock.

Keywords: 1946 Nankai earthquake, witness

Empirical forecast of mainshocks based on foreshock activities
- Applied to the specific three regions and inland area of Japan -

*Kenji Maeda[1], Fuyuki Hirose[1]

1.Meteorological Research Institute

1. Introduction
Generally it is quite difficult to distinguish foreshocks from background seismicity before a mainshock occurs. However, it is known that some activities like swarms tend to be followed by large earthquakes. We have investigated statistical features of swarm-like activity and searched for the best parameters to define foreshocks. So far, we have found that such defined foreshock activities are particularly effective for specific three regions in Japan: regions along the Japan trench, off the Izu peninsula region, and in the north-central Nagano prefecture, and proposed best parameters for each regions to define foreshocks. In this study we report the current status of prediction performance for three regions basing on the latest data. Besides, we also demonstrate the preliminary results of prediction performance for the inland area of Japan using the same parameters estimated for the north-central Nagano prefecture.

2. Method
The method to search for parameters for foreshocks that present high prediction performance consists of four steps. 1) To eliminate small aftershocks from the original data. 2) To define foreshock candidates satisfying the condition that earthquakes of count Nf with magnitude >= Mf_0 occur in the segment of the size of D x D degree (latitude x longitude) during the period of Tf days. 3) To set the alarm period of Ta days during which a mainshock is expected to occur after a foreshock candidate is found. 4) To search for the values of D, Mf_0, Tf, Nf and Ta which give high prediction performance for mainshocks with M >= Mm_0 by the grid search method. The prediction performance is measured mainly by dAIC that is defined as the difference of AIC for a stationary Poisson model and a model based on a foreshock activity, and additionally by alarm rate (AR: the fraction of mainshocks alarmed), truth rate (TR: the fraction of foreshock candidates followed by a mainshock), and probability gain (PG: the ratio of mainshock occurrence rate in the predicted space-time to background occurrence rate).

3. Data and Results
1) Along the Japan Trench
By applying the above method to the earthquakes with M >= 4.0 and depth <= 100 km in three regions along the Japan trench, i.e., off Iwate, off Miyagi and off Ibaraki, cataloged by JMA during the period from 1961 through 2010, we obtained the best parameters for foreshocks as D=0.5 degree, Mf_0 =5.0, Tf=10 day, Nf=3, and Ta=4 days to predict mainshocks with M>=6.0. The prediction performance for the latest period from 1961 to 1/31/2016 is expressed as AR=27% (=13/48) and TR=22% (=17/77).
2) Off the Izu Peninsula
Using earthquakes with M >= 3.0 and depth <= 50 km off the Izu peninsula regions during the period from 1977 to 6/31/2013, we obtained the best parameters for foreshocks as D=0.2 degree, Mf_0=3.0, Tf=3 day, Nf=3, and Ta=5 days to predict mainshocks with M>=5.0. The prediction performance from 1977 to 1/31/2016 using the above parameters is expressed as AR=68% (=44/65) and TR=22% (=43/195).
3) In the North-central Nagano Prefecture
Using earthquakes with M >= 2.0 and depth <= 30 km in the north-central Nagano prefecture during the period from 1998 through 2014, we obtained the best parameters for foreshocks as D=0.1 degree, Mf_0=2.0, Tf=1 day, Nf=5, and Ta=5 days to predict mainshocks with M>=5.0. The prediction performance from 1998 to 1/31/2016 using the above parameters is expressed as AR=45% (=5/11) and

TR=12% (=8/69).

4) Inland of Japan

As a preliminary calculation, we apply the parameters obtained for the north-central Nagano prefecture, i.e., D=0.1 degree, Mf_0=2.0, Tf=1 day, Nf=5, and Ta=5 days for mainshocks with M>=5.0, to the inland area of Japan except for Izu. The prediction performance obtained for the period from 1977 to 1/31/2016 is expressed as AR=11% (=9/79) and TR=1.8% (=11/607).

Keywords: earthquake prediction, performance, foreshocks, statistics, empirical relation, Japanese inland area

The Predicting earthquakes/estimation and the historical tsunami.

*Masaru Nishizawa[1]

1.none

1. The historical tsunami in the wilderness researcher has predict the 2011 TOHOKU Great Earthquake. At present it is difficult to make an accurate prediction on the occurrence of earthquake. But these historical tsunami is effective method to a rough prediction.
2. I believe that the electromagnetic wave is most effective method to an accurate prediction on the occurrence of earthquake.

Reference.

(1)YUUGI IINUMA: Historical Tsunami of Sendai Plain. 1995

Keywords: IINUMA YUUGI, Historical tsunami of Sendai plain, Predicting earthquakes, Petition, TOHOKU district great earthquake, Public office

Fig-1 宮城県沖二つの空白域

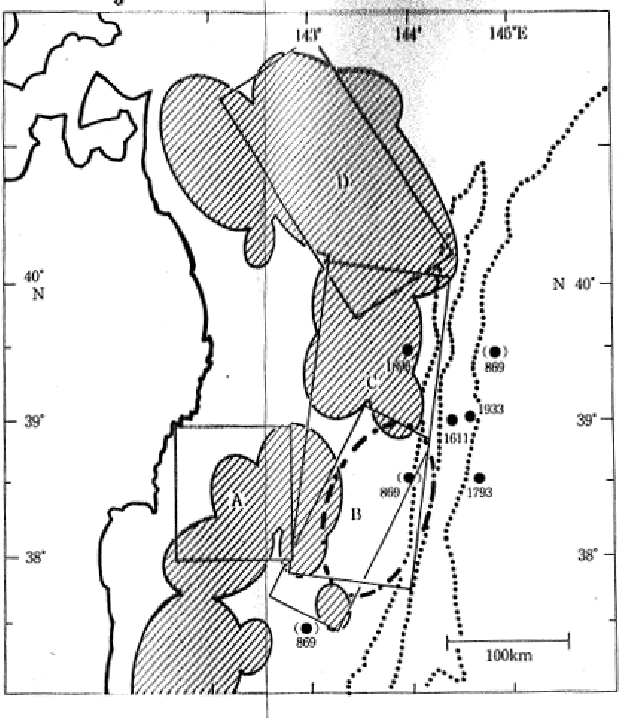
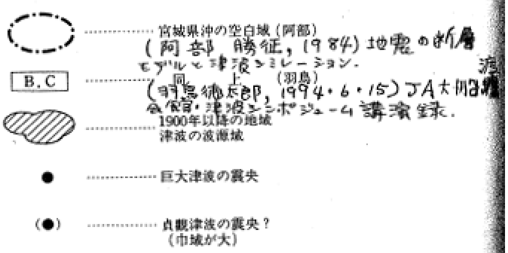


表2 仙台地方の巨大津波の発生海域の震央

巨大津波名	日本年号	西暦	震央	
			東経	北緯
(仮称) 仙台沿岸津波	?	700頃	?	?
貞観津波	貞観11年	869	143°～145°	37.5°～39.5°
慶長津波	慶長16年	1611	144.4°	39°
寛政津波	寛政 5年	1793	144.5°	38.5°
明治三陸津波	明治29年	1896	144°	39.5°
昭和三陸津波	昭和 8年	1933	144°.7°	39.1°



飯沼勇義著「仙台平野の歴史津波」1995
YUUGI IINUMA P. 53，54
「Historical Tunami of Sendai Plain」1995. P53, 54

The To-Nankai E.q. is previous and the Nankai E.q. occurs after it or with it, Elucidation of that mechanism

*Hirofumi Mase[1]

1.none

I explained that the right-turn of slab under Kii Peninsula is the To-Nankai Earthquake, and that the big earthquake which neighbors on it isn't also a simple plate boundary earthquake(1)(2)(3). I studied details around the turn-center this time. That was the drive part of the first half of the Nankai Earthquake, and of the mechanism that that can't explode first than the To-Nankai. (Please refer to the Fig.)(I call the subducting plate or slave the Lower, and call the part upper than it the Upper.)

The power that the mantle which flows to the east relatively pushes the edge of the Lower directly and makes the Lower turn to the right is the turn-drive-force(1). The reactions of it occur widely, but symbolic 6 are representation of all(Fig.1). The west(Area A) from the turn axis(fulcrum) is east-west extension area certainly by the reaction. At the east(Area B) from the fulcrum, doing a nose-dive from the shallow place and after forming the almost horizontal part, shocks will approach the Lower and be the part of make-landing(Sec.y5-Sec.y8). The Lower crawling up with turning rubbs, involves and assimilates the Upper that is rotated in advance. The horizontal part of preparations (turning face) will be formed so. I indicated the turning face at yellow coloring territory and indicated the part of make-landing at gray coloring territory (an orange broken line, centerline) (Fig.2). At the more east(Area C) I can't check the part of make-landing(Sec.y9-Sec.y10). Because the turn in the Lower is moderate (radius large) here, I think the Upper isn't captured.

High-density "High-speed body" touches the peninsula and goes through the Upper and Lower(each Fig. referring)(5). That's a man-shaped who consists of head and body, and depth 40km is neck. There will be time when movement and pressure in Area B shaves or improve, conversely, the "High-speed body" in existence. I regard the neck(Fig.1,depth 40km blue coloring) as the core which stays while thinning. Because the Lower is divided into a inside turn(Area B) and a outside turn(Area C) by collision with the core, and the outside turn is making a wide turn(Fig.1, black broken line arrow), the Lower separate inevitably in east and west at the south from the core. I think the rub of two boards causes pressure and increases density like an rubbing face of a stone-hand-mill and I think the discoid head is formed by it. But the head isn't plane symmetry in depth 25km(Fig.1,2,loop contour). Material partiality to the south and west is seen more in the upper part of the head.

Red arrows of Fig.2 are the observational data(7) by which the inside turn and the outside turn are surely indicated. The To-Nankai Earthquake was a right turn in the large-scale area which has started in the red asterisk from crushing in the Lower(1)(Fig.1). This is the outside turn. The real inside turn that mostly depends on interference of the rubbing face of the stone-hand-mill requires facts that the Lower can turn and advance to a shallow part. In other words, pressing-force-reduction from the outside-turn-part and preceding-destruction in the shallow part are wished for. Is there something equivalent to this inside turn besides The Nankai Earthquake which has started from the blue asterisk 2 years later of the To-Nankai(8)(9)?

(1)MASE/JpGU2014/SSS29-P10(2)MASE/SSJ2014FALL/S08-P11(3)MASE/JpGU2015/SSS31-P15(4)AIST/Visualization system for subsurface structures/all-Japan hypocenter catalog by the JMA/1995-2015/above M1(5)AIST/same to(4)/tomography data by Abdelwahed and Zhao (2007)dVp (6)JHOD,JCG/Seafloor Topography of the Plate Boundaries (7)GSI Home Page/ GEODETIC SURVEY/Crustal Movement in Japan/Long-term Information/Horizontal2005/10-2015/10fixed stn.NAKAMURA (8)(9)indicated on the

drawing

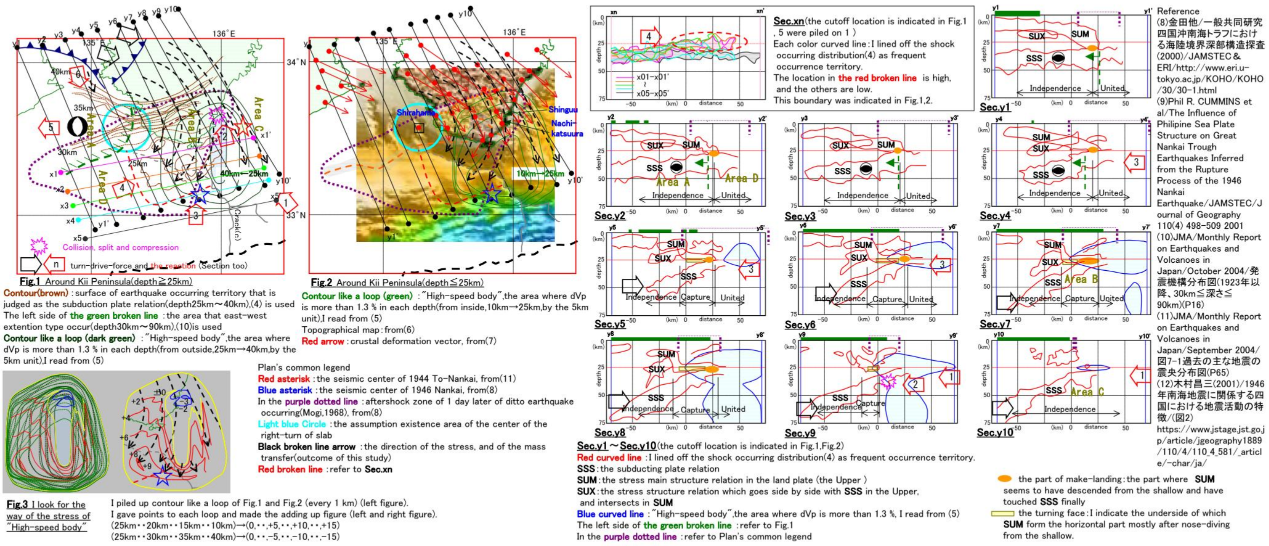


Fig.1 Around Kii Peninsula(depth≧25km)
Contour(brown) : surface of earthquake occurring territory that is judged as the subduction plate relation(depth25km～40km),(4) is used
The left side of the green broken line : the area that east-west extention type occur(depth30km～90km),(10)is used
Contour like a loop (dark green) : "High-speed body",the area where dVp is more than 1.3 % in each depth(from outside,25km→40km,by the 5km unit),I read from (5)
Collision, split and compression
turn-drive-force and the reaction (Section too)
Fig.2 Around Kii Peninsula(depth≦25km)
Contour like a loop (green) : "High-speed body",the area where dVp is more than 1.3 % in each depth(from inside,10km→25km,by the 5km unit),I read from (5)
Topographical map : from(6)
Red arrow : crustal deformation vector, from(7)
Plan's common legend
Red asterisk : the seismic center of 1944 To-Nankai, from(11)
Blue asterisk : the seismic center of 1946 Nankai, from(8)
In the purple dotted line : aftershock zone of 1 day later of ditto earthquake occurring(Mogi,1968), from(8)
Light blue Circle : the assumption existence area of the center of the right-turn of slab
Black broken line arrow : the direction of the stress, and of the mass transfer(outcome of this study)
Red broken line : refer to Sec.xn
Fig.3 I look for the way of the stress of "High-speed body"
I piled up contour like a loop of Fig.1 and Fig.2 (every 1 km) (left figure).
I gave points to each loop and made the adding up figure (left and right figure).
(25km・・20km・・15km・・10km)→(0,・・,+5,・・,+10,・・,+15)
(25km・・30km・・35km・・40km)→(0,・・,-5,・・,-10,・・,-15)
Sec.xn(the cutoff location is indicated in Fig.1 , 5 were piled on 1)
Each color curved line : I lined off the shock occurring distribution(4) as frequent occurrence territory.
The location in the red broken line is high, and the others are low.
This boundary was indicated in Fig.1,2.
Sec.y1～Sec.y10(the cutoff location is indicated in Fig.1,Fig.2)
Red curved line : I lined off the shock occurring distribution(4) as frequent occurrence territory.
SSS : the subducting plate relation
SUM : the stress main structure relation in the land plate (the Upper)
SUX : the stress structure relation which goes side by side with SSS in the Upper, and intersects in SUM
Blue curved line : "High-speed body",the area where dVp is more than 1.3 %, I read from (5)
The left side of the green broken line : refer to Fig.1
In the purple dotted line : refer to Plan's common legend
the part of make-landing : the part where SUM seems to have descended from the shallow and have touched SSS finally
the turning face : I indicate the underside of which SUM form the horizontal part mostly after nose-diving from the shallow.
Reference
(8)金田他/一般共同研究四国沖南海トラフにおける海陸境界深部構造探査(2000)/JAMSTEC＆ERI/http://www.eri.u-tokyo.ac.jp/KOHO/KOHO/30/30-1.html
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(10)JMA/Monthly Report on Earthquakes and Volcanoes in Japan/October 2004/発震機構分布図(1923年以降、30km≦深さ≦90km)(P16)
(11)JMA/Monthly Report on Earthquakes and Volcanoes in Japan/September 2004/図7-1過去の主な地震の震央分布図(P65)
(12)木村昌三(2001)/1946年南海地震に関係する四国における地震活動の特徴/(図2)
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