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

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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;

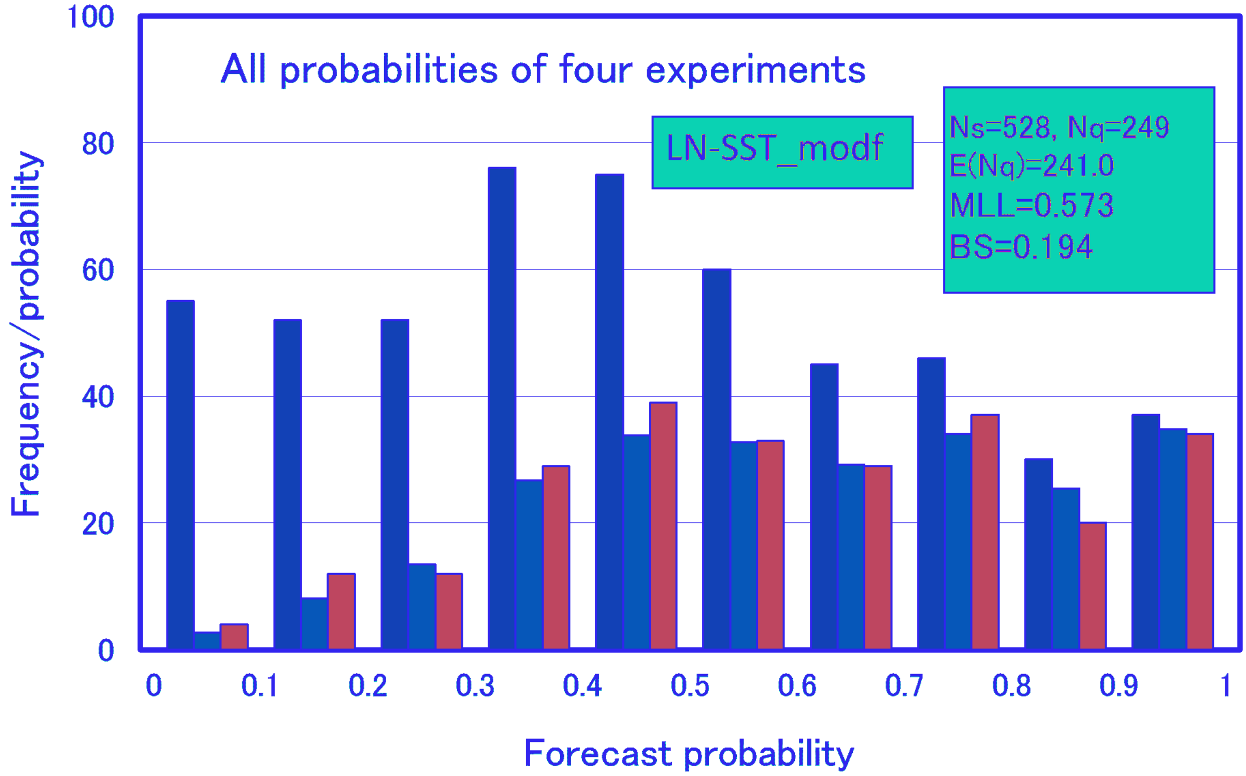
(1) Keep a definition of Z mentioned above intact and increase the degree of freedom.

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

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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

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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

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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

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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?

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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

