as proposed by Heaton and Cochard and Madariaga. Another is spontaneous healing due to heterogeneity of initial conditions proposed by Mikumo and Beroza. These two mechanisms are very different, in the former healing propagates at supershear speeds, while in the second subshear healing was found in some initial models of self-similar self-healing faults. We report on some general results about healing in shear faulting. Using Kostrov's 1994-1966 theory we demonstrate that healing fronts are propagating singularities of lower order than rupture fronts with no localised energy flow into or out of the fault. In many models healing is incomplete leaving small residual slip rates, on others healing can be total. We demonstrate that healing is a very effective method to reduce energy release during seismic rupture and unstable shear slip. Partial or total healing reduces the energy available for rupture to propagate, favoring ruture arrest and reducing seismic radiation.

NG62B MCC: Hall C Saturday 1330h

Scaling, Cascades, and Predictability of Earthquakes Posters *(joint with S, T)*

Presiding: **V G Kossobokov,** International Institute of Earthquake Prediction Theory**; I Zaliapin,** University of California, Los Angeles

NG62B-0946 1330h POSTER

Estimation of Maximum Magnitude (c-value) and its Certainty for Modified Gutenberg-Richter Formulas, Based on Historical and Instrumental Japanese Intraplate Earthquake Catalogs

Takashi KUMAMOTO[1] (+81-86-251-7880; tkuma@cc.okayama-u.ac.jp)

Yukio HAGIWARA[2] (+81-3-3295-1966)

[1]Dept. Earth Sciences, Okayama University, Tsushimanaka 3-1-1, Okayama 7008530, Japan

[2]Association for the Development of Earthquake Prediction, Sarugakucho 1-5-18, Chiyoda-ku, Tokyo 1010064, Japan

A-, b-, and c-values for the original Gutenberg-Richter formula (GR) and modified GR formulas (Utsu, 1978) were estimated using a dataset of combined historical (1595-1925 A.D.) and instrumental (1926-2000) Japanese earthquake data for 18 intraplate seismotectonic provinces depicted on a new tectonic map of Japan (Kakimi et al., 2002). The theoretical relationships between the b-values of the original and modified GR formulas, and the certainty of b- and c-values, were evaluated with respect to the dataset.

The GR formula generally used for earthquake magnitude and frequency relationships demonstrates that earthquake frequency in each magnitude class is about ten times that of the next highest class. This is expressed as: log n(M) = a-bM, where n(M) is the number of earthquakes of a given magnitude M, and a- and b-values are constants representing the level of seismicity and the ratio of small to large events, respectively. In this formula, the expected maximum magnitude (c-value) in a given earthquake catalog is calculated using one more assumption: a maximum-magnitude earthquake should occur only once in a given period, because the c-value is not a characteristic parameter of the original GR formula. Utsu (1978) proposed that the GR formula be modified by introducing the c-value, and presented two formulas: a truncated GR formula (TGR), expressed as log n(M) = a - bM (M is equal to or smaller than c); n(M) = 0 (M is greater than c); and a modified GR formula (MGR), expressed as log n(M) = a - bM + log (c-M) (M is smaller than c); n(M) = 0 (M is equal to or greater than c).

Calculations for 18 Japanese seismo-tectonic provinces revealed the following relation: b(GR) > b(TGR) > b(MGR). This is a theoretical relationship, which means that b- and c-values are relative parameters within one formula, and that comparison of b- and c-values between different GR formulas is meaningless. Furthermore, the distribution of b- and c-values in 18 intraplate seismo-tectonic provinces indicates that b- and c-values are very sensitive to the parameter Ms, which is the lower limit of magnitude above which the dataset is thought to be complete. Thus, it is necessary to ascertain that b- and c-values are stable with respect to Ms, and that c-values are appropriate to maximum magnitude when estimating these parameters within a given earthquake catalog and seismo-tectonic province.

Reference:

Kakimi, T., Matsuda, T, Kinugasa, Y., and Aida, I, 2002, A seismotectonic province map in and around the Japanese islands, submitted to Jour. Seimol. Soc. Japan (Zishin2).

Ustu, T, 1978, Estimation of Parameters in Formulas for Frequency-Magnitude Relation of Earthquake Occurrence, Jour. Seimol. Soc. Japan (Zishin2), 31, 367-382.

NG62B-0947 1330h POSTER

(Multi)fractality of Earthquakes by use of Wavelet Analysis

Bogdan Enescu[1] (+81-774-38-4234; benescu@rcep.dpri.kyoto-u.ac.jp)

Kiyoshi Ito[1] (ito@rcep.dpri.kyoto-u.ac.jp)

Zbigniew R. Struzik[2] (Zbigniew.Struzik@cwi.nl)

[1]Res. Center for Earthquake Pred., Disast. Prev. Res. Inst., Kyoto University, Gokanosho, Uji, Kyoto 611-0011, Japan

[2]Nat. Res. Inst. for Mathematics and Computer Science, P.O. Box 94079, Amsterdam NL-1090 GB, Netherlands

The fractal character of earthquakes' occurrence, in time, space or energy, has by now been established beyond doubt and is in agreement with modern models of seismicity. Moreover, the cascade-like generation process of earthquakes -with one "main" shock followed by many aftershocks, having their own aftershocks- may well be described through multifractal analysis, well suited for dealing with such multiplicative processes.

The (multi)fractal character of seismicity has been analysed so far by using traditional techniques, like the box-counting and correlation function algorithms. This work introduces a new approach for characterising the multifractal patterns of seismicity. The use of wavelet analysis, in particular of the wavelet transform modulus maxima, to multifractal analysis was pioneered by Arneodo et al. (1991, 1995) and applied successfully in diverse fields, such as the study of turbulence, the DNA sequences or the heart rate dynamics. The wavelets act like a microscope, revealing details about the analysed data at different times and scales. We introduce and perform such an analysis on the occurrence time of earthquakes and show its advantages. In particular, we analyse shallow seismicity, characterised by a high aftershock "productivity", as well as intermediate and deep seismic activity, known for its scarcity of aftershocks. We examine as well declustered (aftershocks removed) versions of seismic catalogues.

Our preliminary results show some degree of multifractality for the undeclustered, shallow seismicity. On the other hand, at large scales, we detect a monofractal scaling behaviour, clearly put in evidence for the declustered, shallow seismic activity. Moreover, some of the declustered sequences show a long-range dependent (LRD) behaviour, characterised by a Hurst exponent, H > 0.5, in contrast with the memory-less, Poissonian model. We demonstrate that the LRD is a genuine characteristic and is not an effect of the time series probability distribution function. One of the most attractive features of wavelet analysis is its ability to determine a local Hurst exponent. We show that this feature together with the possibility of extending the analysis to spatial patterns may constitute a valuable approach to search for anomalous (precursory?) patterns of seismic activity.

URL: http://www.rcep.dpri.kyoto-u.ac.jp/∼benescu/

NG62B-0948 1330h POSTER

Evidences of Complexity of Magnitude Distribution, Obtained From a Non-parametric Testing Procedure

Stanislaw Lasocki (48-12-6173811; lasocki@geol.agh.edu.pl)

University of Mining and Metallurgy Faculty of Geology, Geophysics and Environmental Protection, al. Mickiewicza 30, Krakow 31-115, Poland

Complexity of magnitude distribution, that is the presence of more than one mode or more than one bump in its density, is indicative for mixing of components in the population. Parametric testing procedures that test sample data against a specific assumed model often cannot provide convincing evidences of such a complexity. If a complex model of the distribution is not rejected its appropriateness is not certain yet. To the contrary, if a log-linear or smoothly non-linear model is rejected this does not indicate that no other model of this class fits the data.

To study the complexity of magnitude distribution we used a smoothed bootstrap test for multimodality, which is non-parametric, model-free and data driven. Two null hypotheses were investigated: H0(1): the number of modes in magnitude density = 1 and H0(2): the number of bumps in magnitude density = 1. The probability of the null hypotheses turned out to be extremely low for global large earthquake data and for some local catalogs e.g. the Southern California data. Since the tested hypotheses were very general the obtained results distinctly evidence multicomponental structure of magnitude distribution.

NG62B-0949 1330h POSTER

Fractal asperities, invasion of barriers, and prediction of the Tokai earthquake

Tetsuzo Seno (81-3-5841-5747; seno@eri.u-tokyo.ac.jp)

Earthquake Res Inst, Univ of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo 113-0032, Japan

I present a model to explain seismicity variations along plate boundaries: (1) plate boundary fault zones consist of asperities and barriers, which are defined as having negative and positive a - b values, respectively, of rate and state dependent friction laws, (2) circular-shaped asperities are distributed in a fractal manner so that within an order n asperity, a number of Na order n+1 (smaller) asperities are contained, whose radius is $1/\lambda$ of that of an order n asperity, (3) pore fluid pressure can be elevated almost to the lithostatic only in barriers (called invasion of barriers), and (4) a region whose barriers are invaded can rupture as an earthquake when asperities inside break. I derive scaling relations of fault parameters between successive order asperities. The observed relation between fault area and seismic moment and the size-ratio between nearby repeating earthquakes off northern Honshu give Na = 9, λ = 4.8, and the fractal dimension of asperities to be 1.4.

I applied this model to predict the Tokai earthquake, a great interplate earthquake expected off central Honshu. I assume that the rupture zone is part of an order 0 asperity in which barriers have been invaded, and that the Tokai earthquake will happen when any one of order 1 asperities inside the rupture zone breaks. I also assume that barriers within any order 1 asperity are not invaded, because if they are, breakage of this order 1 asperity occurs easily, and the Tokai earthquake would have happened already. Then smaller asperities within the order 1 asperities slip slowly, which explains the gradual uplift relative to the steady subsidence, seen for the past decade, on the peninsula above the rupture zone. I calculate uplifts due to slow slips of the smaller asperities contained in the rupture zone, assuming that the probability of breakage of the smallest asperities increases linearly over time, and an order n asperity breaks when more than or equal to a number of Nb order n+1 asperities break within it. This produces a critical point for breakage of asperities, but an order 1 asperity breaks a little bit earlier. I conduct a least squares fitting to the residual uplift data and obtain the time of failure for the Tokai earthquake as AD 2007.6 (-5.4, +2.8).

URL: http://www.eri.u-tokyo.ac.jp/seno

NG62B-0950 1330h POSTER

BATH'S LAW AS A CONSEQUENCE OF MAGNITUDE DISTRIBUTION

Rodolfo Console[1] (0039-06-51860417; console@ingv.it)

Murru Maura[1] (0039-06-51860412; murru@ingv.it)

Anna Maria Lombardi[1] (0039-06-51860349)

[1]Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605, Rome, RM 00143, Italy

We revisit the issue of the so-called Bath's law concerning the difference D1 between the magnitude of the mainshock, M0, and the second largest shock, M1, in the same sequence. Various authors, in the past, observed that this difference is approximately equal to 1.2. Feller demonstrated in 1966 that the D1 expected value was about 0.5 given that the difference between the two largest random variables of a sample, N, exponentially distributed is also a random variable with the same distribution. Feller's proof leads to the consequence that the mainshock comes from a sample, which is different from the one of its aftershocks. A mathematical formulation of the problem is developed here, the only assumption being that all the events belong to the same self-similar set of earthquakes following the Gutenberg-Richter magnitude distribution with a constant b-value. Assuming that the number of aftershocks in each aftershock series is known, and not extremely large, this model shows a substantial dependence of D1 on the magnitude thresholds chosen for the mainshock and its largest aftershock. In this way it explains the large D1 values reported in the past. Analysis of the PDE catalog of shallow earthquakes demonstrates a good agreement between the average D1 values predicted by the theoretical model and those observed. Limiting our attention to the average D1 values, Bath's law doesn't seem to strongly contradict the Gutenberg-Richter law. Nevertheless, a detailed analysis of the observed D1 distribution shows that the Gutenberg-Richter hypothesis doesn't fully explain the experimental observations. The theoretical distribution has a larger proportion of low D1 values and a smaller proportion of high D1 values than the experimental observations. A reasonable explanation for this mismatch, which appears a minor effect with respect to what was supposed in the past, seems to consist in the byes (not assumed in the model) that the selection of clustered events produces on the average b-value.

URL: http://www.ingv.it

NG62B-0951 1330h POSTER

Data compression and Information in data sequences: Examples and implications for geophysical data

Dario Benedetto[1]

Emanuele Caglioti[1]

Vittorio Loreto[1] (+39 06 49 91 34 37; loreto@pil.phys.uniroma1.it)

Luciano Pietronero[1]

[1]Universita degli Studi di Roma "La Sapienza", P.le A. Moro 5, Roma 00185, Italy

In this talk we present a very general method to extract information from a generic string of characters (a text, a DNA sequence or a generic time-series). Based on data-compression techniques, its key point is the computation of a suitable measure of the remoteness between two sequences. The key idea is that an information on the remoteness of two strings A and B can be obtained zipping the file A+B obtained by appending the string B after the string A.

We show the existence of a universal scaling function (the so-called learning function) which rules the way in which the compression algorithm behaves at the interface between two regions characterized by different properties (e.g. before and after a large event). The existence of a crossover length in this learning process could be exploited for segmentation purposes, i.e. to identify and single out in real time a change in the statistical properties of a given sequence.

Finally we consider some applications of the method and we discuss the implications for the analysis of earthquake catalogs and other geophysical data.

URL: http://pil.phys.uniroma1.it/~loreto/complexity.htm

NG62B-0952 1330h POSTER

Stabilizing intermediate-term earthquake prediction in California and Nevada

Leontina Romashkova[1] (lina@mitp.ru)

Vladimir Kossobokov[1,2] (volodya@mitp.ru)

[1]International Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences, 79-2 Warshavskoye Shosse, Moscow 117556, Russian Federation

[2]Institute de Physique du Globe de Paris, 4 Place Jussieu,, Paris 75252, France

The results of global testing, 1985-present, have established the high statistical significance of the intermediate-term medium-range predictions of the largest earthquakes determined with a help of the M8 and MSc algorithms. Predictions make use of registered near-real time seismic activity to reduce consecutively time and space where targeted earthquake has to be expected. The methodology could be used for routine time-dependent estimations of seismic risk.

A new scheme of applying intermediate-term middle-range earthquake prediction algorithm M8 is proposed. The scheme accounts for natural distribution of seismic activity totally eliminating subjectivity in positioning areas of investigation and providing additional stability of predictions. The improved algorithm, named M8S, was designed in course application of M8 aimed at prediction of earthquakes of moderate size. The essence of the M8S algorithm is the analysis of multiple application of the M8 algorithm in circles of investigation centred at nodes of a fine grid that span seismic territory. If the data permits, the M8S algorithm delivers a hierarchy of predictions related to a number of magnitude ranges $M_0+ = (M_0, M_0 + \Delta M)$. Originally, the two magnitude ranges defined by $M_0 = 6.5$ and 6.0 were tested on the Italian data. Here we extend the M8S predictions to the two different magnitude ranges defined by $M_0 = 6.5$ and 7.0 on the territory of California and Nevada. The retrospective prediction of the earthquakes occurred in 1985-2002 years is consistent with the previous results of M8 application and pattern recognition of the earthquake prone areas in the region.

NG62B-0953 1330h POSTER

Quantitative Mapping of Precursory Seismic Quiescence Before Large Aftershocks

Samuel Neukomm[1] (sneukomm@student.ethz.ch)

Stefan Wiemer[1] (stefan@seismo.ifg.ethz.ch)

Domenico Giardini[1] (giardini@seismo.ifg.ethz.ch)

[1]Swiss Seismological Service, ETH Hoenggerberg, HPP P5, Zurich 8093, Switzerland

A relative decrease of aftershock activity before the occurrence of large aftershocks to M6+ mainshocks is one of only few earthquake precursors accepted for the IASPEI preliminary list of significant earthquake precursors. If one considers earthquake rate to be dependent on stressing rate, aftershocks sequences offer in fact an ideal environment to detect precursory quiescence before large earthquakes: The numerous aftershocks allow a much higher spatial and temporal resolution of transients in seismicity than possible with the average background rate of micro-earthquakes. Past studies of precursory quiescence before larger aftershocks, however, have largely been based on bulk value. The aim of this study is to map the temporal and spatial variability of activity rate within several rich aftershock sequences, and, possibly, exploit the results for improving real time probabilistic aftershock hazard assessment.

We introduce a new algorithm based on fitting the modified Omori law to the aftershock sequences. At arbitrarily chosen grid points, the Omori parameters of the sub-samples containing all aftershock within 5 or 10 km of the node are estimated at time t. We calculate the number of aftershocks N +/- dN in the time interval t + dt using the relevant four Omori parameters (p, c and k) parameters and their corresponding standard deviations estimated using a bootstrap analysis. The difference between the forecasted and the observed number of aftershocks, normalized by the standard deviation of the forecast, is our estimator of rate change.

The algorithm is tested on synthetic aftershock sequences containing artificial quiescences in order to calibrate the free parameters for optimal detection of precursory quiescence. We then perform our spatial and temporal mapping for several prominent Californian and Japanese aftershock sequences (Landers, Hector Mine, Northridge, Loma Prieta, Kobe, Western Tottori and Hokkaido). Preliminary results suggest that we cannot reproduce the positive results of past studies on precursory seismic quiescence before large aftershocks. While some larger aftershocks are preceded locally by relative quiescence, numerous unrelated quiescences of higher significance exist within the aftershock volume. The strongest limitation of our current analysis method is certainly the use of the modified Omori law in its original form; secondary aftershocks sequences to larger aftershocks are not treated naturally

NG62B-0954 1330h POSTER

On an interrelation between seismicity and the electric signals that precede rupture, based on the natural time-domain

Nicholas V. Sarlis[1] (72 76 735; nsarlis@cc.uoa.gr)

Panayiotis A. Varotsos[1] (96 17 573; pvaro@otenet.gr)

Efthimios S. Skordas[1] (72 76 735; eskordas@phys.uoa.gr)

[1]Solid Earth Physics Institute Department of Physics, University of Athens, Panepistimiopolis, Zografos, Athens 157 84, Greece

In recent publications (P. Varotsos, N. Sarlis and E. Skordas, "Long-range correlations in the electric signals that precede rupture." *Phys. Rev. E*, **66**, 011902, (2002), *VJ of Biol. Phys. Res.*, July 15, (2002); "Spatio-temporal complexity aspects on the interrelation between Seismic Electric Signals and Seismicity." *Practica of Athens Academy*, **76**, 388-425, 2001) a new time-domain, termed "natural" time, was proposed. This was motivated by the theory of critical phenomena. In the case of a signal comprised of N pulses, the "natural" time is introduced by ascribing the value χ_k=k/N to the k-th pulse. If Q_k denotes the corresponding pulse duration, a new representation (χ_k,Q_k) of the original signal is obtained. The power spectrum analysis in this domain reveals that: (1) all the Seismic Electric Signals activities (SES) almost coincide with a "universal" curve with parameters consistent with those expected from a critical behavior, (2) the continuous inspection of the power spectrum, in the "natural" time-domain, of the evolving seismicity (after the SES recording) in the candidate area, reveals that it almost coincides with that of the preceding SES activity (in the low frequency range). The data analysis shows that this "collapse" seems to occur only a few days before the occurrence of the mainshock. Thus, since the spectrum of the SES is known in advance, the continuous inspection of the spectrum of the evolving seismic activity may lead to an estimation of the time window of the impending main shock with an accuracy of around a few days, (3) the SES activities are distinguished from "artificial" noises because they fall in different classes of curves. In order to investigate whether the procedure suggested has a wide applicability, the ionic current fluctuations in membrane channels (ICFMC) have been also analyzed in the "natural" time-domain. The results reveal certain spectrum characteristics that indicate usefulness in the biological sciences as well.

NG62B-0955 1330h POSTER

Investigation of the features of the seismicity spectrum in a new time-domain

Efthimios S. Skordas[1] (72 76 735; eskordas@phys.uoa.gr)

Panayiotis A. Varotsos[1] (96 17 573; pvaro@otenet.gr)

Nicholas V. Sarlis[1] (72 76 735; nsarlis@cc.uoa.gr)

[1]Solid Earth Physics Institute Department of Physics University of Athens, Panepistimiopolis, Zografos, Athens 157 84, Greece

Based on the concept of the "natural" time-domain proposed recently (e. g., P. Varotsos, N. Sarlis and E. Skordas, "Long-range correlations in the electric signals that precede rupture." *Phys. Rev. E*, **66**, 011902, (2002); *VJ of Biol. Phys. Res.*, July 15, 2002), a long period study of the seismicity in (1) Greece and (2) California was made (P. Varotsos, N. Sarlis and E. Skordas, "Seismic Electric Signals and Seismicity: On a tentative interrelation between their spectral content", *Acta Geophys. Pol.*, **50**, 337-354, 2002). In the case of a series of earthquakes comprised of N events, the "natural" time is introduced by ascribing the value χ_k=k/N to the k-th event. If we denote with M_k the corresponding seismic moment M_o, a new representation (χ_k, M_k) of the original series of earthquakes is obtained. The analysis of the power spectrum $\Pi(\phi)$ in the "natural" time-domain reveals certain characteristics that are similar in both areas. The calculation was made in each case by considering a number of subsequent events, e.g. from 6 to 40, and scanning the whole catalogue. The distribution function of $\Pi(\phi)$ was plotted for various values of frequency ϕ defined in the "natural" time-domain. The local maxima of these distribution functions correspond to values that lie very close to those estimated from a model based on the theory of critical phenomena. Comparing the two areas (1) and (2), only slight differences in the shape of the distribution functions were noticed that were attributed to different b-values of the Gutenberg-Richter relation in the areas under investigation. Moreover, the position of the local maxima coincide with the $\Pi(\phi)$-values obtained from an independent analysis of the seismic electric signal activities in the natural time-domain.

NG62B-0956 1330h POSTER

Mean Field Threshold Systems and Phase Dynamics: An Application to Earthquake Fault Systems

Kristy F Tiampo[1] (303-492-4779; kristy@cires.colorado.edu)

John B Rundle[2] (rundle@cires.colorado.edu)

William Klein[3] (klein@buphy.bu.edu)

Seth McGinnis[1] (sethmc@turcotte.colorado.edu)

Susanna J Gross[1] (sjg@strike.colorado.edu)

[1]CIRES, University of Colorado UCB 216, Boulder, CO 80309-0216, United States

[2]Center of Computational Science and Engineering, University of California, Davis, CA 95616, United States

[3]Department of Physics, Boston University, Boston, MA 02215, United States

Earthquake dynamics are considered to be one example of a strongly correlated, high dimensional driven threshold system(Burridge & Knopoff, 1967). Such driven meanfield threshold systems demonstrate complex observable space-time patterns of behavior that are difficult to understand or predict without knowledge of the underlying dynamics, which are typically unobservable. Here we describe a new method based on the application of phase dynamics to historic seismicity to analyze and forecast the space-time patterns of activity in these systems (Tiampo et al, 2002). This technique characterizes the seismicity by normalizing to the background rate, in order to define a coarse-grained measure of the spatio-temporal clustering. Application to earthquake data from a typical, seismically active region, southern California, shows that the method provide considerable insight and information regarding the underlying physical process and temporal dynamics of the earthquake fault system.

NG62B-0957 1330h POSTER

Time-Clustering Behavior of Spreading-Center Seismicity Between 15-35 N on the Mid-Atlantic Ridge: Observations from Hydroacoustic Monitoring

DelWayne R Bohnenstiehl[1] (8453658382; del@ldeo.columbia.edu)

Maya Tolstoy[1]

Deborah K Smith[2]

Christopher G Fox[3]

Robert P Dziak[4]

[1]Lamont-Doherty Earth Observatory of Columbia University, PO Box 1000, 61 Route 9W, Palisades, NY 10964, United States

[2]Woods Hole Oceanographic Institution, Deptment of Geology and Geophysics, Woods Hole, MA 02529, United States

[3]Pacific Marine Environmental Lab/NOAA, Hatfield Marine Science Center, Newport, OR 97365, United States

[4]Oregon State University, Hatfield Marine Science Center, Newport, OR 97365, United States

An earthquake catalog derived from the detection of seismically-generated Tertiary (T) waves is used to study the time-clustering behavior of moderate-size (> 3.0 M) earthquakes along the north-central Mid-Atlantic Ridge. Because T-waves propagate efficiently within the ocean's sound channel, these data represent a significant improvement relative to the detection capabilities of land-based seismic stations. In addition, hydroacoustic monitoring overcomes many of the spatial and temporal limitations associated with ocean-bottom seismometer data, with the existing array being deployed continuously between 15-35 degrees N during the period February 1999-Februrary 2001.Within this region, the distribution of inter-event times is consistent with a non-random clustered process, with a coefficient of variation greater than 1.0. The clustered behavior is power-law in nature with temporal fluctuations characterized by a power spectral density that decays as $1/f^{\alpha}$. Using Allan Factor analysis, α is found to range from 0.12-0.55 for different regions of the spreading axis. This scaling is negligible at time scales less than 3.5 x 10^3 s, and earthquake occurrence becomes less clustered (smaller α) as increasing size thresholds are applied to the catalog. The highest degrees of clustering are associated temporally with large mainshock-aftershock sequences; however, some swarm-like activity also is evident. The distribution of acoustic magnitudes, or source levels, is consistent with a power-law size-frequency scaling for earthquakes. Although such behavior has been linked closely to the fractal nature of the underlying fault population in other environments, power-law fault size distributions have not been widely observed in the mid-ocean ridge setting.

URL: http://www.ldeo.columbia.edu/~ del

NG62B-0958 1330h POSTER

Generalizing the Gutenberg-Richter scaling law

Anastasia Nekrasova[1] (nastia@mitp.ru)

Vladimir Kossobokov[1,2] (volodya@mitp.ru)

[1]International Institute of Earthquake Prediction Theory and Mathematical Geophysics, Russian Academy of Sciences, 79-2 Warshavskoye Shosse, Moscow 113556, Russian Federation

[2]Institute de Physique du Globe de Paris, 4 place Jussieu, Paris Cedex 05, France

The evident heterogeneity of seismic distribution in space and time requires special approaches. The patterns of seismic dynamics are apparently scalable to smaller magnitudes according to the generalized Gutenberg-Richter recurrence law that takes into acount the fractal nature of faults and fault zones. We revisit the results of global analysis of the distribution of earthquake size, which takes into account the spatial similarity of the set of epicentres at a given location, to conclude that (i) a seismic region, in a wide range of magnitudes and sizes, can be characterized by the following recurrence law: Log N(M,L) = A - B (M - 5) + C Log L, where N(M,L) is the expected annual number of main shocks of magnitude M within an area of liner size L; (ii) C ranges from under 1 to 1.6 and correlate with the geometry of tectonic features; (iii) an estimate of the local earthquake recurrence depends on the size of the territory that is used for averaging. We draw a comparison between the Generalized Gutenberg-Richter Law (Kossobokov and Mazhkenov, 1988), GGRL, and the Unified Scaling Law for Earthquakes (Bak et al, 2002), USLE, and apply them in a simplistic approximation of the Global Seismic Risk Assessment. The confirmed multiplicative scaling changes the view of traditional mechanics on the recurrence of earthquakes in an epicenter zone and has serious implications for estimation of seismic hazard, as well as for earthquake prediction.

NG62B-0959 1330h POSTER

Multiscale trend analysis: a new approach to studying complex time series

Andrei Gabrielov[1] (agabriel@math.purdue.edu)

Ilya Zaliapin[2,3] (zal@ess.ucla.edu)

Vladimir Keilis-Borok[2,3,4] (vkb@ess.ucla.edu)

[1]Departments of Mathematics and Earth and Atmospheric Sciences, Purdue University, West Lafayette, IN 47907, United States

[2]Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90095, United States

[3]International Institute for Earthquake Prediction Theory and Mathematical Geophysics, Warshavskoe sh., 79, korp. 2, Moscow 113556, Russian Federation

[4]Department of Earth and Space Sciences, UCLA, Los Angeles, CA 90095, United States

Practically every time series emerging in science involves interplay of trends at different scales. Obvious examples are alternations of seismic activation and quiescence, intermittence of warming and cooling of atmosphere and ocean, upward and downward slopes of a landscape, etc. Information on these trends is very important in many problems ranging from classical statistical interpolation of time series to prediction of natural disasters. Powerful Fourier and wavelet analyses are not always convenient since they reflect information on trends only indirectly.

We introduce a new technique for decomposition of time series into a hierarchy of trends at different scales. As a result, a time series is represented by a tree whose nodes correspond to single trends. The larger is the scale at which the trend is observed, the higher in the tree is the corresponding node.

Various applications of the multiscale trend analysis are demonstrated using fractal Brownian motion, and synthetic and observed seismicity.

URL: http://www.igpp.ucla.edu/mcdonnell

NG62B-0960 1330h POSTER

Relationship between stress heterogeneity and mode-switching dynamics of earthquake analogue automata

Dion Weatherley[1] (61 7 3365 4853; dion@quakes.uq.edu.au)

Peter Mora[1] (61 7 3365 2128; mora@quakes.uq.edu.au)

[1]QUAKES, University of Queensland, Brisbane, Qld 4072, Australia

Results from a previous parameter space study of a class of statistical fractal earthquake analogue automata, indicated that these models display two distinct stable modes of dynamical behaviour. Within a certain regime of the parameter space, mode-switching dynamics was observed in which a given model dynamically switches behaviour from one mode to the other and back again. Cursory examination of stress field evolution during mode-switches suggested that the degree of small-scale heterogeneity of the stress field is responsible for instigating a mode-switch. In the present study, a more extensive parameter space study is performed to explore the relationship between stress field evolution and mode-switching. The investigation involved varying the value of an exponent (p) which governs the rate of decay of the long-range stress transfer from failed sites. The time-averaged mean stress of simulations versus the interaction exponent has the signature of a phase transition. For $p < 1$, the time-averaged mean stress remains relatively low and the models produce quasi-periodic characteristic large events. As $p \to 2$, the time-averaged mean stress rapidly rises to a peak at $p = 2$ then begins to drop again for $p > 2$. Event size-scaling is power-law at $p = 2$ with a slope of $b = 1.5$, a value identified with mean-field spinodal dynamics. Within the transition regime ($1 < p < 2$), simulations mode-switch between spinodal dynamics and characteristic events. Stress correlation evolution analysis confirms a distinct difference in the character of the stress field for each mode and sheds light on the mechanism responsible for mode-switching. By the nature of the stress transfer mechanism, events correlate the stress field within the failed region and decorrelate the stress field outside the failed region. Thus, characteristic events tend to correlate the stress field over a broad region whereas the smaller power-law scaling events tend to decorrelate the stress field. When the stress field becomes sufficiently decorrelated across the entire model, spinodal dynamics ensues and only smaller power-law scaling events occur. A switch back to characteristic events is achieved by the progressive phasing up in time of the largest power-law events until a significant fraction of the model fails in a single larger event. The correlating effect of such an event switches the model back to a period of quasi-periodic characteristic events until such time that the smaller events decorrelate the stress field, instigating another mode-switch to spinodal dynamics.

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Statistical Test of the Load-Unload Response Ration using the Lattice Solid Model and the Implication to Tidal Triggering

Yucang Wang[1] (61-7-3365-2176; wangyc@quakes.uq.edu.au)

Peter Mora[1] (61-7-3365-2128; mora@quakes.uq.edu.au)

David Place[1] (61-7-3365-2176; place@quakes.uq.edu.au)

[1]QUAKES, Dept. of Earth Sciences, The University of Queensland, St Lucia, Brisbane, QLD 4072, Australia

Statistical tests of Load-Unload Response Ratio signals are carried using the Lattice Solid Model. In each test, 24 samples with the same macroscopic parameters (tidal perturbation amplitude A, period T and tectonic loading rate k) but different random arrangements of particles are studied. A sinusoidal stress perturbation is added to the constant loading rate of "tectonic" stress build-up to simulate loading and unloading cycles induced by tidal forces. LURR is calculated as the ratio of cumulative seismic energy release during loading to that during unloading within a given time window. Results of uni-axial compression experiments show that before the normalized time of catastrophic failure, the ensemble average LURR values rise significantly, in agreement with the observations of high LURR prior to the large earthquakes. In shearing tests, two parameters are found to control the correlation between earthquake occurrence and tidal stress. One is decided by A/(kT), controlling the phase shift between the peak seismicity rate and the peak amplitude of the perturbation stress. With an increase of this parameter, the phase shift is found to decrease. Another parameter,AT/k , controls the height of the probability density function (pdf) of modeled seismicity. As this parameter increases, the pdf becomes sharper and narrower. It suggests that larger A and smaller k causes stronger correlation between tidal stress and seismicity. Besides A and k, the period of tidal stress, T, also plays an important role in tidal triggering of earthquakes. When T is too small, tidal effects can-not be observed. This may be another possible reason to explain why tidal triggering has not been widely observed. Except in strong triggering cases, where LURR can not be calculated due to poor data in unloading cycles, statistics of LURR signals in shearing tests suggest that the larger events are more likely to occur when LURR is high than the smaller events, supporting the LURR hypothesis.

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Earthquakes Scaling Laws: Are Independent?

Cataldo Godano[1] (++390823274638; cataldo.godano@unina2.it)

Mariarosaria Falanga[2] (++3908995216; rosfal@sa.infn.it)

Salvatore De Martino[2] (++3908995216; demartino@sa.infn.it)

[1]Dipartimento di Scienze Ambientali - Seconda Universit di Napoli, Via Vivaldi 43, Caserta, Ita 81100, Italy

[2]Dipartimento di Fisica - Universit di Salerno, Via S. Allende, Salerno, ita 80100, Italy

Earthquakes exhibit three well known scaling laws: Gutenberg - Richter (GR) frequency magnitude relation, the Omori law and the multifractal distribution of epicenters. We shall show that there exist two relations between the scaling exponente of these relations. In particular the b value shall be proportional to the correlation dimension of the epicenter distribution trough the fractal dimension of the fault trace and the p exponent of the Omori law shall be proportional to the b value trough a new parameter (the decaing of the enrgy in a cluster. The first relation comes out from very simple geometrical considerations while the second needs of the assumption that the temporal behaviour of the energy can be factorised in two terms. The first asimptotically decreasing and the second a stationary one with a power law distribution.

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