The subject of studying surface waves is receiving new attention because of the potential in using surface waves for prediction of physical properties of near surface marine sediments. However, processing of surface waves normally relies on algorithms, which are do not allow sufficient discrimination between surface waves modes. This work extends and recast the results of our previous studies on the wavelet cross-correlation analysis of surface waves. To perform a better resolution in the group and phase velocities inversion now we introduce multiscale cross-correlation in the spatial and time domains. We applied the wavelet transform to seismic traces 'Wa(t[ime],f[requency])' and 'Wb(t[ime],f[requency])' and then calculate the cross-correlation function in the time domain < Wa(t,f,X)*Wb(t-tau,f,X)> and additionally carry out the cross correlation of wavelet fields in horizontal direction X (distance along the interface) <WCR(tau,f,X)*WCR(tau,f,X-X')>. The moduli and phases of multiscale cross-correlation function present the group and phase velocities values at given frequencies and time delay with the spatial resolution defined as a minimum spatial lag X' (minimum distance between receivers). The advantage of using the cross-correlation in both spatial and time domains is obvious as it extracts the information of coherent strength (moduli) and phase in terms of periods (frequencies), time delay and spatial shift and allows to monitor the changes of these parameters in both time and horizontal distance. We present a comparison of using 1D and 2D multiscale cross-correlation techniques in terms of resolving the phase and group velocities of surface waves. We also show the shear velocity profile as a function of depth for the top part of the sediments along the field area. These results also were compared with existing geological data from the field area.

NG12A-1022 1330h POSTER

Investigation of Anisotropy Over the Ethiopian Plateau With Remote Sensing Data: a Scale by Scale Study of the Anisotropy With Fast Fourier Transform and 2D Structure Function

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Scale invariance investigations are now commonly used in a lot of geophysical fields, and the presence of scaling or multiscaling is often revealed over large range of scales. However, most of the time, scaling analyses are done with the assumption of self-similarity, which is inappropriate since anisotropy is a common feature in every aspect of the earth interior and surface. A previous study has shown that remote sensing images from the Ethiopian plateau exhibit scale invariance over range of scales between 35 m and 15 km. Using Fast Fourier Transform and 2D structure functions of remote sensing data (Landsat TM, ERS-1 and ASTER) over different areas (drainage and plateau) and in various bands of the electromagnetic spectrum (visible, SWIR and microwave), we investigate anisotropy scale by scale over the Ethiopian plateau. Distinct anisotropic features (topography, chemical composition, structural features) can be observed depending on the bands of the electromagnetic spectrum inspected. The scale invariance parameters observed over the Ethiopian plateau will be examined using the results of this new investigation.

NG12A-1023 1330h POSTER

Visual Computing of Global Postglacial Rebound in a Spherical Domain

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Postglacial rebound is usually presented as a bunch of static greyscale emotionless images. Yet the process is intrinsically fascinating from a dynamical standpoint because of many interactive physical elements. We present here a visual tour of the postglacial rebound processes taken from an initial value approach applied to a self-gravitating viscoelastic spherical Earth. Our formulation allows us to handle both elastic compressibility and arbitrary style of parameter stratification in the radial direction. We employed pseudospectral techniques on Chebyshev staggered grids. Resulting ordinary differential equations form a numerically stiff initial value problem. We solve it to receive explicit time-dependent Love numbers and subsequently the physical fields. We have developed an Amira data format based on a moving curvilinear mesh and tailored to animate time evolution of the displacement vector in a spherical domain, which consists of an outer half-sphere, a radial cross-section and a CMB half-sphere. Moreover, the format contains one degree of freedom, which allows to save simultaneously responses of any number of independent Earth models and to visualize interactively mutual differences in any time and a spatial point. Color scaling, zooming and changing the view direction provided by the Amira software serve as an enhancement in the inversion. As an example, we computed a set of 360 Love numbers in the PREM mantle discretized by an unevenly spaced Chebyshev grid consisting of 300 nodes. For a given ice coverage, we then combined the Love numbers into the displacement vector on the above described domain with the angular grid of 1 × 1 degree in 100 interpolated time instants. It takes 12 min of 2-GHz CPU time to prepare a resulting binary data set amounting to 300 MB per one Earth model. Even for a hundred different models, we can still visualize Amira 30-GB data sets with a speed allowing truly interactive work. Here we have concentrated on the effects of elastic compressibility, lithospheric depth and asthenospheric width. Special attention is devoted to illustrate the complexity of horizontal displacements of compressible models in the near zone of ice sheets.

NG12B MCC: Hall C Monday 1330h

Fractals, Chaos, and SOC in Natural and Human-Induced Hazards Posters

(joint with A, B, H, OS, S, V, GC)

Presiding: **S Tebbens,** University of South Florida**; S Burroughs,** University of Tampa

NG12B-1024 1330h POSTER

The Ramifications of Meddling with Systems Governed by Self-organized Critical Dynamics

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Complex natural, well as man-made, systems often exhibit characteristics similar to those seen in self-organized critical (SOC) systems. The concept of self-organized criticality brings together ideas of self-organization of nonlinear dynamical systems with the often-observed near critical behavior of many natural phenomena. These phenomena exhibit self-similarities over extended ranges of spatial and temporal scales. In those systems, scale lengths may be described by fractal geometry and time scales that lead to 1/f-like power spectra. Natural applications include modeling the motion of tectonics plates, forest fires, magnetospheric dynamics, spin glass systems, and turbulent transport. In man-made systems, applications have included traffic dynamics, power and communications networks, and financial markets among many others. Simple cellular automata models such as the running sandpile model have been very useful in reproducing the complexity and characteristics of these systems. One characteristic property of the SOC systems is that they relax through what we call events. These events can happen over all scales of the system. Examples of these events are: earthquakes in the case of plate tectonic; fires in forest evolution extinction in the co evolution of biological species; and blackouts in power transmission systems. In a time-averaged sense, these systems are subcritical (that is, they lie in an average state that should not trigger any events) and the relaxation events happen intermittently. The time spent in a subcritical state relative to the time of the events varies from one system to another. For instance, the chance of finding a forest on fire is very low with the frequency of fires being on the order of one fire every few years and with many of these fires small and inconsequential. Very large fires happen over time periods of decades or even centuries. However, because of their consequences, these large but infrequent events are the important ones to understand, control and minimize. The main thrust of this research is to understand how and when global events occur in such systems when we apply mitigation techniques and how this impacts risk assessment. As sample systems we investigate both forest fire models and electrical power transmission network models, though the results are probably applicable to a wide variety of systems. It is found, perhaps counter intuitively, that apparently sensible attempts to mitigate failures in such complex systems can have adverse effects and therefore must be approached with care.

The success of mitigation efforts in SOC systems is strongly influenced by the dynamics of the system. Unless the mitigation efforts alter the self-organization forces driving the system, the system will in general be pushed toward criticality. To alter those forces with mitigation efforts may be quite difficult because the forces are an intrinsic part of the system. Moreover, in many cases, efforts to mitigate small disruptions will increase the frequency of large disruptions. This occurs because the large and small disruptions are not independent but are strongly coupled by the dynamics. Before discussing this in the more complicated case of power systems, we will illustrate this phenomenon with a forest fire model.

NG12B-1025 1330h POSTER

A Simple Model for the Earthquake Cycle Combining Self-Organized Criticality with Critical Point Behavior

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We have studied a hybrid model combining the forest-fire model with the site-percolation model in order to better understand the earthquake cycle. We consider a square array of sites. At each time step, a "tree" is dropped on a randomly chosen site and is planted if the site is unoccupied. When a cluster of "trees" spans the site (a percolating cluster), all the trees in the cluster are removed ("burned") in a "fire." The removal of the cluster is analogous to a characteristic earthquake and planting "trees" is analogous to increasing the regional stress. The clusters are analogous to the metastable regions of a fault over which an earthquake rupture can propagate once triggered. We find that the frequency-area statistics of the metastable regions are power-law with a negative exponent of two (as in the forest-fire model). This is analogous to the Gutenberg-Richter distribution of seismicity. This "self-organized critical behavior" can be explained in terms of an inverse cascade of clusters. Individual trees move from small to larger clusters until they are destroyed. This inverse cascade of clusters is self-similar and the power-law distribution of cluster sizes has been shown to have an exponent of two. We have quantified the forecasting of the spanning fires using error diagrams. The assumption that "fires" (earthquakes) are quasi-periodic has moderate predictability. The density of trees gives an improved degree of predictability, while the size of the largest cluster of trees provides a substantial improvement in forecasting a "fire."

NG12B-1026 1330h POSTER

Re-examination of the 1975 Kalapana, Hawai'i tsunami using a fractal source model

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The effect of source complexity on the 1975 Kalapana tsunami, triggered by a M_S=7.2 earthquake, is examined using a stochastic, self-affine model (i.e., variance changes with scale) for earthquake and landslide movements. Runup observations for the 1975 tsunami were recorded along the southern and western shores of the Island of Hawai'i with a maximum runup of 7.9 m recorded at Halape, near the center of the earthquake rupture area. The tsunami was also recorded on several tide gauges stations on the Hawaiian Islands, including the Hilo station. Previous analysis of the source processes for the tsunami (Ma et al., 1999) indicated that either the rupture area extended farther offshore than indicated by the aftershock distribution or that localized submarine slumping occurred during the earthquake. Past studies used uniform-slip dislocation models to compute initial conditions for the tsunami generated by the earthquake. To account for earthquake source complexity, a stochastic source model is used with a slip spectrum that decays as a function of k^{-2}, where k is the radial wavenumber within the rupture area. This model corresponds with the generic ω^{-2} decay in the far-field seismic displacement spectrum observed for many earthquakes. Ground displacements from localized landslides offshore are also prescribed to follow a power-law scaling relationship. The initial tsunami wavefield is calculated for

both earthquake-generated and hybrid (earthquake and landslide) sources using a standard tsunami Green's function in which small-scale seafloor displacements are filtered out. Results indicate that self-affine complexity in earthquake rupture and landslide movements results in significant variations in broadside runup (i.e., directly across from the source region). For oblique and refracted propagation paths, such as to the local tide gauge stations, the effects of source complexity are substantially attenuated.

NG12B-1027 1330h INVITED POSTER

A Universal Landslide Distribution and an Associated Landslide-Event Magnitude Scale

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An earthquake, a rapid snowmelt, or a large storm can trigger a landslide event, ranging from a few individual landslides to several thousand. The frequency-area (or frequency-volume) distribution of a triggered-landslide event describes the frequency of landslides that occur at different sizes. We examine three landslide events, from different parts of the world and with different triggering mechanisms, and find that all three have the same "universal" landslide distribution, a three-parameter inverse gamma distribution, which for small events has an exponential "roll-over" and for medium and large events has a power-law tail. One implication of this universal distribution is that the mean area of the landslides in the distribution is about 3070 m^2, and is independent of the size of the event. We also introduce a landslide-event magnitude scale, $M_L = \log(N_{LT})$, with N_{LT} the total number of landslides triggered by the event. If an inventory of triggered landslides is not complete (i.e., only the largest landslides have been compiled), the density of landslides of a given size can be compared with the "universal" landslide distribution, and the corresponding landslide event magnitude inferred. One can extend this technique to inventories of historic\geologic landslides inferring the number of landslides that occurred over geologic time, and how many of these were erased from the landscape by erosion and mass-wasting. Landslides are clearly extremely complex, and include many different physical processes over different scales. However, earthquakes are also extremely complex. The Richter earthquake magnitude scale is certainly approximate, but has found great use since its introduction. Even with its obvious limitations, we suggest that our proposed landslide magnitude scale will also be very useful.

NG12B-1028 1330h POSTER

Scale Invariant Relationships for Snow Avalanches

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Snow avalanches have been described as the most common form of lethal mass wasting in the mountains of the western United States and result in more than 30 fatalities per winter. In this poster, we investigate scale-invariant relationships associated with snow avalanches to better understand some of the complex interactions of the snow avalanche system. This work utilizes over 20 years of data from a number of ski areas and other avalanche-prone locations in the western United States. Our results reveal power-law relationships between avalanche frequency and size for several groups of avalanche paths. Further, following some recent work by others, we also demonstrate a power law between avalanche frequency and the estimated fracture depth of the avalanches for groups of avalanche paths in several different snow climates. Interestingly, the relationships explored are valid both for datasets consisting largely of avalanches artificially triggered with explosives as well as for datasets consisting entirely of natural avalanches. Recent research by others also demonstrates scale invariance in the fracture and fragmentation of ice. Our work suggests that scale invariance may also exist in the complicated fracture processes within seasonal snowpacks that result in the release of slab avalanches.

NG12B-1029 1330h POSTER

Self-Similar Criticality: A Model for Forest Fire Burn Areas

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Many natural phenomena exhibit power-law frequency-size distributions and are modeled as self-organized critical (SOC) systems. Examples include earthquakes, forest fires, and landslides, which are associated with the slider-block, forest fire, and sand pile SOC models, respectively. As originally proposed, SOC models generate event frequency-size distributions that follow a power law with a single scaling exponent. The slider-block SOC model was modified to produce a range of scaling exponents, consistent with distributions observed for naturally occurring earthquakes. Forest fire burn areas have been found to follow power law frequency-size distributions with scaling exponents that depend on study location. In the original forest fire SOC model, events are triggered at randomly selected locations and follow a cumulative distribution described by a single scaling exponent. In self-similar criticality (SSC) models, events are triggered on a fractal distribution of critical grid cells and the scaling exponent of the resulting distribution depends on the fractal dimension of the critical cells. The SSC model applied to forest fires generates distributions with a range of scaling exponents, as is observed for forest fire burn areas in nature. The SSC model may provide a link between fractal geometry of topography and observed power law frequency-size distributions of forest fire burn areas.

NG12B-1030 1330h POSTER

PERCOLATING MAGMAS AND EXPLOSIVE VOLCANISM

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Magma rising in conduits depressurizes and forms bubbles by the exsolution of gas. In Bingham magmas (i.e. with finite yield strength), when the bubble fraction (P) reaches a value of the order 0.7, the magma fragments, explosive eruption occurs. From percolation theory as P approaches a critical porosity Pc the size of the largest bubble diverges. We apply this result to magmas. Whereas in liquid magmas attaining Pc would have little rheological significance and P could increase to much higher values (e.g., scoria), on the contrary, in stressed Bingham magmas percolation implies a singularity in the overall rheology triggering an explosion. This straightforward mechanism may have been overlooked since classical (monodisperse) continuum percolation theory predicts Pc=0.29850.005, much too low. However, it has recently been shown that the bubble distribution is a power law associated with a huge range of bubble sizes. Using Monte Carlo percolation simulations, we show that distributions using the empirical exponents are very effective at packing, drastically raising Pc to the value =0.700.05. Explosive volcanism is thus explained by singular rheology at Pc.

NG12B-1031 1330h POSTER

New Features of Rescaled Range Analysis of the Running Sandpile With Applications to Geophysical Systems

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Characterizing the dynamics of physical systems is a critical first step toward understanding the underlying governing physical processes. In addition to illuminating the physics, characterization helps to evaluate the validity of models that are compared with the physical systems being studied. One such method of characterization is rescaled range analysis.

Rescaled range analysis was introduced by Hurst to characterize long time correlations in time series. The rescaled range, R/S, is plotted against the time lag, τ, on doubly logarithmic axes and a single power law is fit to the entire curve. The slope of the plot, which is the exponent in the power law, is called the Hurst exponent, H. The value of H indicates whether the dynamics are persistent ($1.0 > H > 0.5$), anti-persistent ($0.5 > H > 0.0$) or uncorrelated ($H = 0.5$). In his initial report, Hurst found persistence ($H \approx 0.7$) in most geophysical data sets that he studied.

Self-organized criticality (SOC) was introduced separately (and much later) as a framework for understanding traits commonly seen in many physical systems, such as power laws in power spectra, bursty activity and long time correlations, among others. The running sandpile model was created and defined as a simple and specific example that displays SOC. Persistence in the long time behavior of this model has been indicated by rescaled range analysis, but only up to time lags on the order of 10^6 for a system of size 10^2. Power spectra, though, indicate that the dynamics change beyond this time. We have extended the R/S analysis by three orders of magnitude and have seen changes in the dynamics, with consecutive regions that change from persistent to anti-persistent to uncorrelated. This indicates that more than one power law fit to distinct sections of the R/S plot (i.e., more than one value of H) may be appropriate in some systems where different dynamics take place on different time scales.

In this work, we put forth an explanation of the dynamics in the different regions of the running sandpile and discuss how the regions scale with drive and system size. We also relate this to physical systems that have been studied using R/S analysis, such as earthquakes and plasmas, where the data sets are limited in length relative to that appropriate for the size, drive and smallest meaningful time step of the particular system. (Size, drive and time step for seismic data could, for example, relate to fault length, slip rate and earthquake intervals, respectively.) Relevant and, perhaps, undiscovered dynamics may be taking place in some physical systems on time scales much longer than the data can presently show.

NG12B-1032 1330h POSTER

Coping With Climate Noise: Long Range Dependence and Weather Derivatives

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Random day-to-day changes in weather lead to random year-to-year fluctuations in monthly and seasonal means, a feature known as "climate noise". Such climate noise has direct economic impact on a wide variety of businesses. A typical example is energy vendors, whose annual revenues are closely correlated with seasonal mean temperatures. To deal with this risk,

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a form of insurance known as weather derivatives has been developed in recent years. We discuss a Monte Carlo approach to the pricing of weather derivatives based on stochastic modeling of daily temperature. It will be shown that this approach can only be succesful if the time-series model correctly captures the autocorrelation structure of the data even at very high lags. Evidence will be presented that observed daily temperatures exhibit long-range dependence, i.e. power-law decay of the autocorrelation. This means that classical Box-Jenkins ARMA models are unequal to the task, since their autocorrelations decay exponentially. A generalisation of ARMA models which explicitly includes long-range dependence does however prove to be suitable, at least in some cases. We also briefly discuss the physical mechanisms which give rise to the long memory found in the data.

NG12B-1033 1330h POSTER

Evaluation and Quantification of Uncertainty in the Modeling of Contaminant Transport and Exposure Assessment at a Radioactive Waste Disposal Site

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The disposal of low-level radioactive waste (LLW) in the United States (U.S.) is a highly regulated undertaking. The U.S. Department of Energy (DOE), itself a large generator of such wastes, requires a substantial amount of analysis and assessment before permitting disposal of LLW at its facilities. One of the requirements that must be met in assessing the performance of a disposal site and technology is that a Performance Assessment (PA) demonstrate "reasonable expectation" that certain performance objectives, such as dose to a hypothetical future receptor, not be exceeded. The phrase "reasonable expectation" implies recognition of uncertainty in the assessment process.

In order for this uncertainty to be quantified and communicated to decision makers, the PA computer model must accept probabilistic (uncertain) input (parameter values) and produce results which reflect that uncertainty as it is propagated through the model calculations. The GoldSim modeling software was selected for the task due to its unique facility with both probabilistic analysis and radioactive contaminant transport. Probabilistic model parameters range from water content and other physical properties of alluvium to the activity of radionuclides disposed to the amount of time a future resident might be expected to spend tending a garden. Although these parameters govern processes which are defined in isolation as rather simple differential equations, the complex interaction of couple processes makes for a highly nonlinear system with often unanticipated results. The decision maker has the difficult job of evaluating the uncertainty of modeling results in the context of granting permission for LLW disposal. This job also involves the evaluation of alternatives, such as the selection of disposal technologies. Various scenarios can be evaluated in the model, so that the effects of, for example, using a thicker soil cap over the waste cell can be assessed. This ability to evaluate mitigation scenarios is of great utility in cost-benefit analysis.

In addition to providing decision makers with realistically uncertain modeling results, probabilistic assessment is also useful in understanding nonlinear model behavior and in guiding research efforts aimed at reducing the uncertainty in key components of the model. A sensitivity analysis of the modeling results identifies which model parameters are most significant (and over which ranges) in determining estimated doses, for example, thus providing justification for the allocation of limited research funding to reduce uncertainty in parameters that are both poorly constrained and significant to the model behavior.

NG12C MCC: Hall C Monday 1330h

Nonlinear Physical Properties of Geophysical Materials Posters *(joint with MR)*

Presiding: **K McCall,** University of Nevada, Reno**; R Guyer,** Los Alamos National Laboratory

NG12C-1034 1330h INVITED POSTER

Neutron Scattering and the Nonlinear Acoustic Properties of Rocks

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Although geomaterials (rocks) have been studied by macroscopic mechanical experiments for a very long time, the complexity, inhomogeneities, multiple phases, fluid content, interfaces, and lack of transparency have defied most experiments to resolve the corresponding microscopic behavior associated with a particular macroscopic observation. The microscopic origin of nonlinearity and hysteresis (end-point memory) evident in macroscopic stress-strain curves of rocks is still unknown after some 30 years of research by many groups, not to mention more recent low strain results like slow dynamics [see, *Physics Today*, **52**, 30-35 (1999)] or hysteretic temperature dependence [*Geophys. Res. Lett.*, **28**, 2293-2296 (2001)]. Although models of the P-M space variety have developed to a degree where some good qualitative agreement is reached, the link to the actual physical microscopic or atomic mechanism for hysteresis is still missing.

Neutron diffraction is one of a few experiments that can lead to an understanding of the atomic or microscopic effects that govern the properties of complex geomaterials. Neutrons can easily penetrate rocks [*Geophys. Res. Lett.*, **28**, 2105-2108, (2001)] and reveal properties of the bulk interior material (rather than the near-surface regions measurable, say, by X-rays). We are performing experiments with rocks on two beamlines at the Lujan neutron facility at Los Alamos where the scattering data will be correlated with some of the large body of nonlinear acoustic data which exists, to determine which atomic-plane level constituents of the rocks are active in nonlinear processes. We will describe the neutron scattering and acoustic experiments we are carrying out on marble and sandstone samples and will present our first results from the LANSCE neutron facility at Los Alamos. [Work supported by Office of Basic Energy Sciences, DOE, with Los Alamos National Laboratory Institutional Support.]

NG12C-1035 1330h POSTER

On Dynamic Nonlinear Elasticity and Small Strain

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We are addressing the question of whether or not there is a threshold strain behavior where anomalous nonlinear fast dynamics (ANFD) commences in rock and other similar solids, or if the elastic nonlinearity persists to the smallest measurable values. In qualitative measures of many rock types and other materials that behave in the same manner, we have not observed a threshold; however the only careful, small strain level study conducted under controlled conditions that we are aware of is that of TenCate et al. in Berea sandstone (*Phys. Rev. Lett.* **85**, 1020-1024 (2000)). This work indicates that in Berea sandstone, the elastic nonlinearity persists to the minimum measured strains of at least 10^{-8}. Recently, we have begun controlled experiments in other materials that exhibit ANFD in order to see whether or not they behave as Berea sandstone does. We are employing Youngs mode resonance to study resonance peak shift and amplitude variations as a function of drive level and detected strain level. In this type of experiment, the time average amplitude is recorded as the sample is driven by a continuous wave source from below to above the fundamental mode resonance. The drive level is increased, and the measurement is repeated progressively over larger and larger drive levels. Experiments are conducted at ambient pressure. Pure alumina ceramic is a material that is highly, elastically-nonlinear and nonporous, and therefore the significant influence of relative humidity on elastic nonlinear response that rock suffers is avoided. Temperature is carefully monitored. Measurements on pure alumina ceramic show that, like Berea sandstone, there is no threshold of elastic nonlinearity within our measurement capability. We are now studying other solids that exhibit ANFD including rock and mixed phase metal. These results indicate that elastic nonlinearity influences all elastic measurments on these solids including modulus and Q at ambient conditions. There appears to be no nonelastic linear behavior threshold in these solids.

NG12C-1036 1330h POSTER

A Dynamic Model of Hysteretic Elastic Sysytems

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The McCall-Guyer (MG) model for the description of elastic systems having hysteresis with end point memory, consists of a chain of hysteretic elastic elements with properties that depend on an Ising-like state variable. A system of coupled differential equations, one for the displacement field and a second for the state variable are introduced. These equations are the generalization to dynamics of the MG model. The state variable has Brownian dynamics in an energy landscape with structure that is sensitive to the forces which the elastic element must support. Numerical studies of the model yield behavior that compares well with the behavior of physical realizations of hysteretic elastic systems with end point memory, e.g., a Berea sandstone in both quasi-static and dynamic experiments. The generalization of the model to the cases where the elastic system is coupled to auxiliary fields and/or to a thermal reservoir is described.

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Comparison of β Values in Rocks Deduced From the Elastoacoustic Effect and From 3-Wave Mixing

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We measure the changes in the speeds of sound in Berea, wet and dry, due to the application of non-isotropic stresses (elastoacoustic effect). From these measurements we deduce values of the 3rd order elastic constants, A, B, C. We insonify these same samples, immersed in a water tank, with well-characterized acoustic signals having frequency content $f_1 = 1.05MHz$ and $f_2 = 0.95MHz$. The nonlinear properties of the samples generate a difference frequency component at $\Delta f = 100kHz$ whose amplitude we measure (3-wave mixing). We analyze the combined effects of diffraction, attenuation, and nonlinearity on these difference frequency signals by means of the KZK equation, suitably modified to account for the actual frequency dependence of the attenuation in these samples. The attenuation of the higher frequency nonlinear signals, $f_1 + f_2, 2f_1, 2f_2$, precludes our ability to measure them. The values of β deduced from the 3-wave mixing measurements are in the hundreds whereas the values of β implied by the values of A, B, C are in the thousands. The same experiments on lucite yield β values consistent with each other: $\beta \approx 6$. In lucite we are easily able to measure the higher frequency nonlinear signals. The high attenuation in rocks precludes their measurement at these frequencies.