DOE/ER/14425--T1

MEETING REPORT: WORKSHOP ON REDUCTION AND PREDICTABILITY OF NATURAL DISASTERS

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Natural hazards such as earthquakes and severe floods are a continual menace to large segements of the population worldwide. Recently the United Nations has focused attention on this global problem by declaring the 90's the Decade of Natural Hazard Reduction. In addition to the obvious threat to human life natural hazards can cause severe economic hardship locally and, in an ever more complex and interactive world economy, dislocations that are felt in areas far beyond the region of a specific event.

An example of the economic problems posed by natural hazards is the recent series of catastrophic earthquakes, hurricanes, floods and fires that have called into question the ability of private insurers to cover the economic losses. Unlimited liability is a necessity for confidence in insurance coverage; however, recent events have stretched the resources of all insurers, even the largest. Failure of insurers to cover the costs of rebuilding a major population center such as San Francisco or Tokoyo would have repercussions on a global scale. For reasons of both public safety and world wide economic security it is essential that a greater ability to predict the severity and frequency of large catastrophic events be developed.

To address these concerns a workshop on Reduction and Predictability of Natural Disasters was held at the Santa Fe Institute on January 5-9, 1994. The Santa Fe Institute was originally founded in 1985 to study the emergent properties of complex nonlinear systems seen in a diversity of fields, from physical science to economics to biology. During the workshop, which brought together 25 geologists, geophysicists, hydrologists, physicists, and mathematicians, a wide variety of natural disasters and hazards were considered. These include earthquakes, landslides, floods, tsunamis, hurricanes, and tornadoes.

The general theme of the meeting was the application of the techniques of statistical mechanics to problems in the earth sciences. Important questions considered included:

1) What are the statistics of earthquake occurrence along (i) active plate margins i.e. Los Angeles, Tokoyo, Seattle, (ii) active intraplate zones, i.e. Wasatch front in Salt Lake City; Eastern Sierra near Reno; (iii) active plate interiors (i.e. Mississippi embayment near Memphis; Atlantic margin near Charleston, SC); and inactive plate interiors?

2) Do great earthquakes follow the statistics of smaller regional earthquakes or do they occur more (or less) frequently i.e. are the Gutenberg-Richter relations regionally valid?

3) What is the largest earthquake that can occur in a region?

4) What are the statistics for the occurrence of very large floods and storms such as hurricanes? Is there any physical basis for application of a particular statistical relation, i.e. fractal, log normal, etc?

5) Can flood statistics be obtained from studies of meteorological conditions plus the hydrology of river basins?

6) Have human modifications such as agriculture, flood control projects and channelization made the flooding problem more severe in some cases?

7) What is the validity of using the probability distribution of small events to predict the occurrence of large, extremal events?

A recurrent theme of the presentations was the application of the modern techniques of Statistical Mechanics with particular focus on dynamical systems concepts including fractals, multifractals, chaos, nucleation, self-organizing systems, and critical phenomena.

Speakers on the first two days concentrated on seismic problems. Discussions of observational constraints as well as the development of new tools such as Synthetic Aperture Radar Interferometry were presented by R. Bilham, S. Gross, and J. Rundle, all from the University of Colorado at Boulder.

A variety of multiple slider-block models of single earthquake faults and fault systems were presented by L. Knopoff (UCLA), J. Rundle, W. Klein (Boston U.), A. Herz (Illinois). The models generated extensive discussion of various topics including:

1) ordinary critical versus self-organized critical behavior;

2) the predictability of major slip events;

3) the applicability of the models to either the rupture of a single fault or regional seismicity;

4) and the applicability of new processes of nucleation seen in thermal and magnetic phase transitions to earthquake source mechanisms.

J. Carlson (UCSB) discussed the effectiveness of the Russian M8 prediction algorithm in forcasting synthetic sesmic events generated on a variety of models. B. Minster (UCSD) discussed the robustness of the M8 algorithm to the Loma Prieta and Landers earthquakes. Although the Loma Prieta earthquake was predicted with some confidence, he argued that the Landers earthquake was not and therefore the approach was questioned.

W. Newman (UCLA) discussed allied models for the failure of stranded cables, and he showed that dynamic failure exhibited critical behavior that static failure did not.

C. Sammis (USC) presented box counting studies of the spatial distributions of aftershocks and found fractal behavior. The fractal dimension D of the three dimensional distribution of epicenters was found to be near D=1.8, a value characteristic of the backbone of a percolation cluster. S. Brown (Sandia) presented experimental studies of stick slip and steady sliding friction on granite surfaces using precise measurements of temperature. He found low values of the dynamical friction coefficient as determined by low heat generation in stick slip events, and higher values of friction coefficient implied by high heat generation during steady sliding. The results may explain the "heat flow paradox" on faults, the interpretion being that stick slip occurs in association with significant normal motion (separation) on the fault surface. This phenomenon is similar to the behavior seen in stick slip in foam rubber experiments.

M. Marder (U. Texas) presented laboratory and computational studies of fracture propagation. It has been known for many years that fractures propagate at a velocity that is a small fraction of the theoretically predicted value, which is the Rayleigh wave velocity. Marder found tip instabilities in both his laboratory and numerical experiments that appear to explain the discrepancy. L. Sander (U. Michigan) presented a status report on Diffusion Limited Aggegation a mechanism believed to underlie certain types of fracture and the generation of drainage networks.

The remainder of the meeting was spent discussing a variety of other natural hazards and geomorphic processes. C. Barton (USGS) presented frequency magnitude statistics for hurricanes and tsunamis and argued that they often give a scaling distribution (power law) to a good approximation. S. Nishenko (USGS) presented historical data on the fatalities and dollar loss associated with earthquakes, hurricanes, and tornadoes and also concluded that power law statistics can be used. D. Turcotte (Cornell) argued that flood frequency-magnitude statistics are also power law. He also discussed the relevance of Hurst's R/S analysis and concepts of fractional noise. D. Rothman (MIT) showed a variety of data on the frequency-magnitude thickness statistics of sublacustrine sedimentary sequences, debris flows, and landslides, and found a general applicability of power law statistics. Scaling of the data are predicted by sandpile models of self-organized criticality.

A number of participants discussed recently developed models for the evolution of landforms and drainage networks. S. Nagel (U. Chicago) presented experimental studies of sand avalanches. A nearly periodic series of nearly equal size avalanches was found, more reminiscent of a first order phase transition than the second order transition predicted by the self-organized criticality model. No evidence for a power law distribution was found. Nagel also presented a model for the evolution of drainage networks based on cellular automata. C. Chase (U. Arizona) discussed cellular automata models for the erosional evolution of topography. R. Bras (MIT) discussed a wide variety of the aspects related to the development of drainage networks. B. Troutman (USGS) discussed the generation of random channel networks. V. Gupta (U. Colorado) discussed the foundations of scale invariance in hydrology, and E. Waymire (Oregon State U.) reported on multifractal studies of the spatial distribution of rain in rain storms.

A major feature of the workshop was the interest of all participants in the very broad range of problems considered. Stimulating discussions concerned the application of current techniques in one field to another field, and examples included the spatial and temporal clustering of earthquakes and the appropriate definition of a flood. The relative merits of the variety of slider block (quasistatic vs. elastodynamic), and drainage network (Gibbs vs. diffusive) models were debated. The slider block models clearly provide a basis for testing various earthquake prediction algorithms, and the drainage network models provide a means of evaluating the effects of dams and other drainage-altering events. It was concluded that computer simulations and analysis of these dynamical systems offer
an attractive method for predicting the future evolution of the systems, and for testing a variety of hypotheses.

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